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| (54) Title: OXYGEN SCAVENGERS WITH REDUCED OXIDATION PRODUCTS FOR USE IN PLASTIC FILMS AND BEVERAGE AND FOOD CONTAINERS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                    |  |  |
| <p>EMAC</p> <p>3-Cyclohexene-1-methanol</p> <p>Reactive Extrusion (REX)</p> <p>EMCM</p> <p><i>poly(ethylene/methyl acrylate/cyclohexane-methyl acrylate)</i></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                    |  |  |
| (57) Abstract                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                    |  |  |
| <p>An oxygen scavenger composition, for use in or with plastics materials, includes a polymer or oligomer having at least one cyclohexene group or functionality. The composition produces only low levels of volatile or (extractable from a plastics material in which it is incorporated) products as a consequence of oxygen scavenging. A family of polymers containing selected cyclic allylic pendent groups for oxygen scavenging packaging which has minimal organoleptic by-products after oxidation. Multilayer plastic containers for food and beverage packaging which incorporate oxygen scavenging resins which selectively oxidize upon activation without giving off odorous fragments.</p> |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                    |  |  |

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1     OXYGEN SCAVENGERS WITH REDUCED OXIDATION PRODUCTS FOR  
2     USE IN PLASTIC FILMS AND BEVERAGE AND FOOD CONTAINERS

3

4

5     Field of the Invention

6     The present invention is directed to oxygen scavengers for use in plastics  
7     materials, and in particular plastics films. Emphasis is given to scavengers  
8     which produce low or negligible levels of oxidation by-products which may  
9     contaminate the head space in a package. This invention also relates to a  
10    composition useful in scavenging oxygen from environments containing  
11    oxygen-sensitive products, particularly food and beverage products. More  
12    specifically, the oxygen scavenging composition includes a polymer having  
13    ethylenic unsaturation contained within a cyclic moiety, a transition metal  
14    compound and, optionally, a photoinitiator. The present invention also relates  
15    to compositions for use in areas such as food packaging, and with minimal  
16    effect on odor and taste of packaged contents. The invention preferably uses  
17    ethylene acrylate copolymers which are modified with selected cyclic allylic  
18    pendent groups for use in oxygen scavenging packaging materials. The  
19    present invention also relates to rigid polymeric food or beverage containers  
20    comprising polyester such as polyester terephthalate or polyester naphthalate  
21    and oxygen scavenging polymer.

22

23

24

25     Background of the Invention

26

27     The majority of plastic films produced are employed in some form of  
28     packaging. The present invention is primarily concerned with those films  
29     used for applications requiring a low level of oxygen in a package, though  
30     may also find other uses.

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1 Limiting the exposure of oxygen-sensitive products to oxygen maintains and  
2 enhances the quality and shelf life of many products. For instance, by limiting  
3 the oxygen exposure of oxygen-sensitive food products in a packaging  
4 system, the quality of the food product can be maintained and spoilage  
5 retarded. In addition, such packaging also keeps the product in inventory  
6 longer, thereby reducing costs incurred from waste and having to restock.

7

8 In the food packaging industry, several techniques for limiting oxygen  
9 exposure have been developed. Common techniques include those where  
10 oxygen is consumed within the packaging environment by some means other  
11 than the packaged article or the packaging material (e.g., through the use of  
12 oxygen scavenging sachets), those where reduced oxygen environments are  
13 created in the package (e.g., modified atmosphere packaging (MAP) and  
14 vacuum packaging), and those where oxygen is prevented from entering the  
15 packaging environment (e.g., barrier films).

16

17 The art dealing with barrier packaging, and the low oxygen or modified  
18 packaging of products is relatively well developed. This includes the use of  
19 films and inserts containing oxygen scavenging compounds able to extract a  
20 majority of any residual oxygen after packaging occurs.

21

22 Oxygen scavenging compounds for use in plastic films are relatively well  
23 known. Typically these comprise unsaturated compounds in combination with  
24 a transition metal catalyst. In response to some form of initiation—usually  
25 exposure to light or radiation—the scavengers react with available oxygen in  
26 the package.

27

28 For instance:

29

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1 Michael Rooney, "Oxygen scavenging: a novel use of rubber photo-  
2 oxidation", *Chemistry and Industry*, March 20, 1982, pp. 197-198, describes  
3 the use of ethylenically unsaturated compounds as oxygen scavengers on  
4 exposure to light. However, systems describing the use of transition metal  
5 catalysts are not described.

6

7 US 4,908,151 to Mitsubishi describes sachets containing unsaturated fatty  
8 acid (i.e., an ethylenically unsaturated hydrocarbon) in combination with a  
9 transition metal compound in a basic substance. However, there is no  
10 description of these materials in the form of a film nor the use of photo-  
11 exposure as an initiating mechanism.

12

13 Japanese patent JP5032277 to Kuwa describes the use of radical containing  
14 resin layers in packages. The invention comprises an oxidizable polymer  
15 whose oxygen scavenging abilities is photoinitiated.

16

17 New Zealand patent application NZ241802 to W R Grace and also NZ243077  
18 also to W R Grace, claim oxygen scavenging compositions comprising  
19 ethylenically unsaturated hydrocarbons with transition metal catalysts. A wide  
20 range of ethylenically unsaturated compounds are discussed in the texts of  
21 these specifications though there is no mention of the problems to which the  
22 present invention is directed, nor the compounds and products encompassed  
23 by the present invention.

24

25 Sachets containing an oxygen scavenging compositions can contain ferrous  
26 compositions, which oxidize to their ferric state, unsaturated fatty acid salts on  
27 an absorbent, and/or a metal-polyamide complex. See, e.g., U.S. Patent  
28 Nos. 4,908,151 and 5,194,478. The disadvantages of sachets include the  
29 need for additional packaging steps (to add the sachet to the package), the

1 potential for contamination of the packaged article should the sachet break  
2 and the danger of ingestion by a consumer.

3

4 Oxygen scavenging materials also have been incorporated directly into the  
5 packaging structure. This technique (hereinafter referred to as "active oxygen  
6 barrier") can provide a uniform scavenging effect throughout the package and  
7 can provide a means of intercepting and scavenging oxygen as it passes  
8 through the walls of a package, thereby maintaining the lowest possible  
9 oxygen level throughout the package. Active oxygen barriers have been  
10 formed by incorporating inorganic powders and/or salts as part of the  
11 package. See, e.g., U.S. Patent Nos. 5,153,038, 5,116,660, 5,143,769, and  
12 5,089,323. However, incorporation of such powders and/or salts can degrade  
13 the transparency and mechanical properties (e.g., tear strength) of the  
14 packaging material and can complicate processing, especially where thin  
15 films are desired. Also, these compounds as well as their oxidation products  
16 can be absorbed by food in the container, which can result in the food product  
17 failing to meet governmental standards for human consumption.

18

19 EP 0 519 616 discloses an oxygen scavenging composition that includes a  
20 blend of an epoxide, a first polymeric component grafted with an unsaturated  
21 carboxylic anhydride and/or acid, a second polymeric component including  
22 OH, SH, or NHR<sup>2</sup> groups where R<sup>2</sup> is H, C<sub>1</sub>-C<sub>3</sub> alkyl, or substituted C<sub>1</sub>-C<sub>3</sub> alkyl  
23 moiety, and a metal salt capable of catalyzing the reaction between oxygen  
24 and the second polymeric component. The first polymeric component is  
25 present in an amount sufficient to ensure that the blend is non-phase  
26 separated. A blend of polymers is utilized to obtain oxygen scavenging, and  
27 the second polymeric component is preferably a (co)polyamide such as  
28 MXD6.

29

1 Another type of active oxygen barrier is illustrated in EP-A-0 301 719,  
2 EP-A-0 380 319, PCT Publication No. WO 90/00578, and PCT Publication  
3 No. WO 90/00504. See also U.S. Patent Nos. 5,021,515 5,194,478, and  
4 5,159,005. The disclosed oxygen scavenger includes polyamide-transition  
5 metal catalyst compositions. Through catalyzed scavenging by the  
6 polyamide, the package wall regulates the amount of oxygen reaching the  
7 interior of the package. However, the onset of useful oxygen scavenging (i.e.,  
8 up to about  $5.8 \times 10^{-5} \text{ cm}^3/\text{m}^2 \cdot 24 \text{ hours}$  at ambient conditions) can take as  
9 long as 30 days to occur. Therefore, this technique is not acceptable for  
10 many applications. Further, polyamides typically are incompatible with many  
11 thermoplastic polymers commonly used to make flexible packaging materials  
12 (e.g., ethylene/vinyl acetate copolymers, low density polyethylene, etc.) or,  
13 when used by themselves, are difficult to process and result in inappropriately  
14 stiff structures.

15

16 Oxygen scavenging compositions that include transition metal catalysts and  
17 ethylenically unsaturated hydrocarbon polymers which have an ethylenic  
18 double bond content of from 0.01 to 10 equivalents per 100 grams of polymer  
19 are disclosed in U.S. Patent No. 5,399,289. Various conventional  
20 homopolymers, copolymers, and polymer blends are disclosed. Because  
21 these polymers are amorphous, they can be difficult to blend and process  
22 with film-forming semicrystalline polymers conventionally used to make  
23 flexible packaging materials.

24

25 The use of a transition metal and a photoinitiator to facilitate initiation of  
26 effective scavenging activity of ethylenically unsaturated compounds is taught  
27 in U.S. Patent No. 5,211, 875, which is incorporated herein by reference as if  
28 set forth in full.

29

1 PCT Publication Nos. WO 95/02616 and WO 96/40799 disclose a scavenger  
2 composition that includes a transition metal salt and a copolymer (of ethylene  
3 and a vinyl monomer) having ether, amino, carboxylic acid, ester, or amide  
4 functionalities pendent therefrom. Although these compositions can provide  
5 oxygen scavenging activity, the particular advantages of having ethylenic  
6 unsaturation contained within a cyclic moiety are not disclosed. Because the  
7 compositions of this invention are significantly cleaner than those described in  
8 the prior art, they do not require the use of high levels of adjuncts to absorb  
9 the undesirable byproducts. Such absorbent additives are known in the art,  
10 for example see U.S. 5,834,079 and U.S. 08/857,276. It is also well known in  
11 the art that such additives (zeolites and silicas) adversely affect the haze and  
12 clarity of packaging structures.

13

14 PCT Application WO 96/40799 from Chevron describes the use of a variety of  
15 ethylenic materials with benzylic, allylic or ether containing side chains. Some  
16 of these materials may be prepared by esterification or transesterification of a  
17 polymer melt. The use of pendent cyclic groups containing allylic  
18 unsaturation is generally referred to, but there is only one such example,  
19 wherein Nopol, a bicyclic alcohol, is used in a transesterification reaction and  
20 oxygen absorbing films are formulated from the product. There is no  
21 reference to the benefits of cyclic allylic compounds as described in this  
22 invention i.e., on oxidation they produce very low levels of oxidation  
23 byproducts when compared to comparable linear allylic systems. Because of  
24 its bicyclic nature, Nopol is not expected to produce these benefits.

25

26 While the prior art compounds may effectively scavenge oxygen they  
27 introduce other problems into packaging. For instance, in summary the prior  
28 art incorporates into film structures compounds which are ethylenically  
29 unsaturated but which often cleave as a consequence of the reactions of the  
30 oxygen scavenging process. For example, films containing unsaturated

1 compounds such as squalene or vegetable oils produce large amounts of  
2 volatile aldehydes and ketones upon oxidation. Unfortunately, many of these  
3 volatile compounds are not contained within the film structure and find their  
4 way into the head space of the package. Here they can represent more of a  
5 problem than the oxygen which they have replaced and have the potential to  
6 contaminate comestible products.

7

8 This problem represents a significant problem yet has been downplayed or  
9 overlooked by the published prior art. As a consequence, those searching  
10 the prior art for a solution to this problem find no answer—the art appears to  
11 be directed primarily along a narrow track of improving on scavenging  
12 efficiencies, or physical properties of scavenging films, rather than  
13 recognizing or addressing other associated problems.

14

15 Accordingly the present invention seeks to address the problems associated  
16 with scission products of oxygen scavengers, and seeks also to provide a  
17 group of compounds and substances (as well as films and plastics materials  
18 including same) which have an advantage over the prior art in terms of  
19 reduced quantities of scission products.

20

21 Ideally, a polymeric material for use in an oxygen scavenging composition  
22 should exhibit good processing characteristics, be able to be formed into  
23 useful packaging materials or have high compatibility with those polymers  
24 commonly used to make packaging materials, and not produce byproducts  
25 which detract from the color, taste, or odor of the packaged product. It has  
26 been found that when the ethylenic unsaturation is contained within a cyclic  
27 group, substantially fewer and less byproducts are produced upon oxidation  
28 as compared to analogous non-cyclic materials. Optimally, a packaging

- 1 material formed from such a composition can retain its physical properties
- 2 after significant oxygen scavenging.
- 3
- 4
- 5 New polymer compositions having properties that are particularly tailored for
- 6 specific applications are required in response to more specific and
- 7 sophisticated end uses. It can be difficult to make these compositions directly
- 8 by polymerization from monomers or via solution esterification or
- 9 transesterification, but manufacturing them in melt mixing equipment such as
- 10 an extruder has provided an efficient, economical and viable means to supply
- 11 increasingly complex polymers to meet the needs in specialized markets.
- 12 It is well known that regulating the exposure of oxygen-sensitive products to
- 13 oxygen maintains and enhances the quality and "shelf-life" of the product.
- 14 For instance, by limiting the exposure of oxygen sensitive food products to
- 15 oxygen in a packaging system, the quality or freshness of food is maintained,
- 16 spoilage reduced and the food shelf life extended. In the food packaging
- 17 industry, several means for regulating oxygen exposure have already been
- 18 developed. These means include modified atmosphere packaging (MAP) and
- 19 oxygen barrier film packaging.
- 20 One method currently being used is "active packaging", whereby the package
- 21 containing the food product has been modified in some manner to regulate
- 22 the food's exposure to oxygen. One form of active packaging uses oxygen-
- 23 scavenging sachets which contain a composition which scavenges the
- 24 oxygen through oxidation reactions. One type of sachet contains iron-based
- 25 compositions which oxidize to their ferric states. Another type of sachet
- 26 contains unsaturated fatty acid salts on a particulate adsorbent. Yet another
- 27 sachet contains metal/polyamide complex. However, one disadvantage of

1 sachets is the need for additional packaging operations to add the sachet to  
2 each package. A further disadvantage arising from the iron-based sachets is  
3 that certain atmospheric conditions (e.g., high humidity, low CO<sub>2</sub> level) in the  
4 package are sometimes required in order for scavenging to occur at an  
5 adequate rate. Further, the sachets can present a problem to consumers if  
6 accidentally ingested.

7 Another means for regulating exposure of a packaged product to oxygen  
8 involves incorporating an oxygen scavenger into the packaging structure  
9 itself. A more uniform scavenging effect through the package is achieved by  
10 incorporating the scavenging material in the package instead of adding a  
11 separate scavenger structure (e.g., a sachet) to the package. This may be  
12 especially important where there is restricted airflow inside the package. In  
13 addition, incorporating the oxygen scavenger into the package structure  
14 provides a means of intercepting and scavenging oxygen as it permeates the  
15 walls of the package (herein referred to as an "active oxygen barrier"),  
16 thereby maintaining the lowest possible oxygen level in the package.

17 One attempt to prepare an oxygen-scavenging wall involves the incorporation  
18 of inorganic powders and/or salts. However, incorporation of these powders  
19 and/or salts causes reduction of the wall's optical transparency, discoloration  
20 after oxidation, and reduced mechanical properties such as tear strength. In  
21 addition, these compounds can lead to processing difficulties, especially  
22 when fabricating thin films. The oxidation products may migrate into food at  
23 levels which would not be regarded as safe or can impart unacceptable taste  
24 or smell to food.

25 An oxygen-scavenging composition comprising a blend of a first polymeric  
26 component comprising a polyolefin is known, the first polymeric component  
27 having been grafted with an unsaturated carboxylic anhydride or an  
28 unsaturated carboxylic acid, or combinations thereof, or with an epoxide; a

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1 second polymeric component having -OH, -SH, or -NHR<sup>2</sup> groups where R<sup>2</sup> is  
2 H, C<sub>1</sub>-C<sub>3</sub> alkyl, substituted C<sub>1</sub>-C<sub>3</sub> alkyl; and a catalytical amount of metal salt  
3 capable of catalyzing the reaction between oxygen and the second polymeric  
4 component, the polyolefin being present in an amount sufficient so that the  
5 blend is not phase-separated. A blend of polymers is utilized to obtain  
6 oxygen scavenging, and the second polymeric component is preferably a  
7 polyamide or a copolyamide such as the copolymer of m-xylylene-diamine  
8 and adipic acid (MXD6).

9 Some oxygen scavenging systems produce an oxygen-scavenging wall. This  
10 is done by incorporating a metal catalyst-polyamide oxygen scavenging  
11 system into the package wall. Through catalyzed oxidation of the polyamide,  
12 the package wall regulates the amount of oxygen which reaches the interior  
13 volume of the package (active oxygen barrier) and has been reported to have  
14 oxygen scavenging rate capabilities up to about 5 cubic centimeters (cc)  
15 oxygen per square meter per day at ambient conditions. However, this  
16 system suffers from significant disadvantages.

17 One particularly limiting disadvantage of polyamide/catalyst materials can be  
18 a low oxygen scavenging rate. Adding these materials to a high-barrier  
19 package containing air can produce a package which is not generally suitable  
20 for creating an internal oxygen level of less than 0.1% within seven days at  
21 storage temperatures, as is typically required for headspace oxygen  
22 scavenging applications.

23 There are also disadvantages to having the oxygen-scavenging groups in the  
24 backbone or network structure in this type of polyamide polymer. The basic  
25 polymer structure can be degraded and weakened upon reaction with oxygen.  
26 This can adversely affect physical properties such as tensile or impact  
27 strength of the polymer. The degradation of the backbone or network of the

- 1 polymer can further increase the permeability of the polymer to those
- 2 materials sought to be excluded, such as oxygen.
  
- 3 Moreover, polyamides previously used in oxygen scavenging materials, such
- 4 as MXD6, are typically incompatible with thermoplastic polymers used in most
- 5 flexible packaging walls, such as ethylene-vinyl acetate copolymers and low
- 6 density polyethylene. Even further, when such polyamides are used by
- 7 themselves to make a flexible package wall, they may result in inappropriately
- 8 stiff structures. They also incur processing difficulties and higher costs when
- 9 compared with the costs of thermoplastic polymers typically used to make
- 10 flexible packaging. Even further, they are difficult to heat seal. Thus, all of
- 11 these are factors to consider when selecting materials for packages,
- 12 especially multi-layer flexible packages and when selecting systems for
- 13 reducing oxygen exposure of packaged products.
  
- 14 Another approach to scavenging oxygen is an oxygen-scavenging
- 15 composition comprising an ethylenically unsaturated hydrocarbon and a
- 16 transition metal catalyst. Ethylenically unsaturated compounds such as
- 17 squalene, dehydrated castor oil, and 1,2-polybutadiene are useful oxygen
- 18 scavenging compositions, and ethylenically saturated compounds such as
- 19 polyethylene and ethylene copolymers are used as diluents. Compositions
- 20 utilizing squalene, castor oil, or other such unsaturated hydrocarbon typically
- 21 have an oily texture as the compound migrates toward the surface of the
- 22 material. Further, polymer chains which are ethylenically unsaturated in the
- 23 backbone would be expected to degrade upon scavenging oxygen,
- 24 weakening the polymer due to polymer backbone breakage, and generating a
- 25 variety of off-odor/off-taste by-products.
  
- 26 Other oxidizable polymers recognized in the art include "highly active"
- 27 oxidizable polymers such as poly(ethylene-methyl acrylate-benzyl acrylate),
- 28 EMBZ, and poly(ethylene-methyl acrylate-tetrahydrofuryl acrylate), EMTF,

1 as well as poly(ethylene-methyl acrylate-nopol acrylate), EMNP. Although  
2 effective as oxygen scavengers, these polymers have the drawback of giving  
3 off large amounts of volatile by-products and/or strong odors after oxygen  
4 scavenging.

5 Also known are oxygen-scavenging compositions which comprise a transition-  
6 metal salt and a compound having an ethylenic backbone and having allylic  
7 pendent or terminal moieties which contain a carbon atom that can form a  
8 free radical that is resonance-stabilized by an adjacent group. Such a  
9 polymer needs to contain a sufficient amount and type of transition metal salt  
10 to promote oxygen scavenging by the polymer when the polymer is exposed  
11 to an oxygen-containing fluid such as air. Although effective as oxygen  
12 scavengers, upon oxidation, we have found that allylic pendent groups on an  
13 ethylenic backbone tend to generate considerable amounts of organic  
14 fragments. We believe this is a result of oxidative cleavage. We believe  
15 these fragments can interfere with the use of allylic pendent groups as  
16 oxygen scavengers in food packaging.

17 Multilayer rigid container structures, which utilize an oxygen scavenging  
18 composition, are known. In the container wall, base polymers such as  
19 polyethylene terephthalate have been used along with an oxygen scavenger.  
20 The resulting multilayer package wall includes at least an oxygen scavenger  
21 core layer as well as inner and outer layers having high oxygen barrier  
22 qualities. The oxygen scavenger core layer is a combination of at least an  
23 oxygen scavenging polymer with post consumer-polyethylene terephthalate  
24 (PC-PET). The inner and outer layers include at least oxygen barrier quality  
25 PET.

26

27 Furthermore, multilayered plastic bottles having oxygen scavenging capacity  
28 sufficient to maintain substantially zero or near zero presence of oxygen in

1 the bottle cavity under specified storage conditions have also been disclosed.  
2 The multilayered bottle wall has at least three layers. The inner and outer  
3 layers are PET or another bottling polyester, which define the bottle cavity  
4 and the outside skin of the bottle respectively. Between the inner and outer  
5 layers is an oxygen scavenging copolyester layer.

6

7 Condensation copolymers used for making bottles with polyester such as  
8 PET or polyethylene naphthalate (PEN) have also been disclosed. The  
9 condensation copolymers comprise predominantly polyester segments and  
10 an oxygen scavenging amount of polyolefin oligomer segments. The  
11 copolymers are preferably formed by transesterification during reactive  
12 extrusion and typically comprise about 0.5 to about 12 wt. % of polyolefin  
13 oligomer segments. In a preferred embodiment, a bottle is provided having a  
14 multilayer wall of at least three layers. The outer and inner layers are of  
15 unmodified PET and the oxygen scavenging layer in between the outer and  
16 inner layer is made of the condensation copolymers described above having  
17 an oxygen scavenging amount of polyolefin oligomers.

18

19 A transparent oxygen-scavenging article for packaging oxygen sensitive  
20 products is also known, the oxygen-scavenging article having a multilayered  
21 wall including at least three layers, an inner and outer layer of biaxially-  
22 oriented aromatic polyester polymers such as PET or PEN and an oxygen-  
23 scavenging aromatic ester polymer compatible with the polyester polymer.  
24 The oxygen-scavenging aromatic ester polymer must include ketone carbonyl  
25 groups to provide the oxygen-scavenging functionality and aromatic and ester  
26 groups for compatibility with the polyester.

27

28 PET containers have been disclosed that have a container wall of stretched  
29 plastic material with high oxygen barrier properties and an activating metal  
30 incorporated into the plastic material. The plastic material is PET in admixture

1 with a polyamide and the metal is either added to the mixture or contained in  
2 one or both of the polymers.

3

4 A container containing at least one layer containing a plastics material and  
5 ions of at least one metal has also been disclosed. The plastics material in  
6 the layer consists of at least a partially split or degraded polyamide which has  
7 increased sensitivity to reaction with oxygen in the presence of metal thus  
8 giving the layer improved oxygen barrier properties.

9

10 A container has been disclosed with a wall having high oxygen barrier  
11 properties comprising a molded polymer composition, the composition  
12 comprising a granular mixture of (1) a first polymer providing essential  
13 strength for the container wall and (2) an active component comprising a  
14 metal compound capable of scavenging oxygen and consisting essentially of  
15 a metal ion having complexing properties and a polymer to which said metal  
16 ion is combined as a metal complex in the molded polymer composition of  
17 said wall to scavenge oxygen. There is also disclosed a method of producing  
18 the polymer composition which can be molded into containers, the method  
19 being to treat a polymer with a metal compound dissolved or slurried in a  
20 volatile solvent composition during refluxing conditions for obtaining the active  
21 component having capacity to scavenge oxygen.

22

23 An article has been disclosed with oxygen barrier properties comprising at  
24 least partly a molded polymer composition formed by melting granules of the  
25 composition and molding the melted composition to produce the article. The  
26 composition comprises a granular mixture of (1) a first polymer composition  
27 providing strength for the article and (2) a second polymer composition  
28 compatible with the first polymer composition. The second polymer  
29 composition is obtainable by reacting a polyamide or copolyamide with a  
30 solution of a transition metal compound in a volatile solvent under refluxing

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1 conditions. The polymer of the first polymer composition can be any polymer  
2 and the metal of the metal compound reacted with the polyamide or  
3 copolyamide can be any transition metal. The amount of metal in the second  
4 polymer composition is at least 500 ppm.

5

6 A polymer material having increased sensitivity to reaction with oxygen has  
7 also been disclosed, the polymer material comprising a polyamide, which has  
8 been reacted with a nucleophilic reagent and possibly an activator. The  
9 nucleophilic reagent is selected from the group consisting of compounds  
10 containing at least one hydroxyl group, compounds containing at least one  
11 alkoxide group, phosphate compounds, pyrophosphate compounds,  
12 polyphosphate compounds, salts of organic acids and a copolymer of vinyl  
13 alcohol and ethylene. The activator is in the form of a hydrogen donor. A  
14 process is also disclosed for producing the polymer material, which has  
15 increased sensitivity of reaction with oxygen. In the process, a polyamide  
16 reacts with the nucleophilic reagent under such conditions that the polymer  
17 material is obtained.

18

19 Such polymeric containers of PET, PEN and/or polyamide as described  
20 above utilize oxidizable components to react with and decrease the amount of  
21 oxygen in contact with oxygen sensitive materials packaged in containers. All  
22 of these oxidizable materials have the disadvantage of imparting unpleasant  
23 odor and/or taste to the packaged materials because of the byproducts given  
24 off during the oxidation of the oxidizable materials. Another problem is the  
25 uncontrolled oxidation fragmentation from the polymer backbone which leads  
26 to chain secession, thus weakening the physical integrity of the multilayer  
27 container structures.

28

29

1 The present invention solves many of the problems of the prior art, especially  
2 with an oxygen scavenging packaging material incorporating polymers  
3 comprising cyclic allylic (olefinic) pendent groups which produce little or no  
4 migration of oxidation by-products adversely affecting odor or taste, thus  
5 minimizing organoleptic problems in food packaging. This is because the  
6 cyclic allylic structures are less likely to fragment or cleave after oxidation  
7 than the conventional open chain allylic (olefinic) groups used in oxygen  
8 scavenging packaging material.

9

10 Such polymeric containers of PET, PEN and/or polyamide as described  
11 above utilize oxidizable components to react with and decrease the amount of  
12 oxygen in contact with oxygen sensitive materials packaged in containers. All  
13 of these oxidizable materials have the disadvantage of imparting unpleasant  
14 odor and/or taste to the packaged materials because of the byproducts given  
15 off during the oxidation of the oxidizable materials. Another problem is the  
16 uncontrolled oxidation fragmentation from the polymer backbone which leads  
17 to chain secession, thus weakening the physical integrity of the multilayer  
18 container structures.

19

20 In contrast, the present invention achieves a rigid beverage and food  
21 container comprising PET and/or PEN, the container incorporating an oxygen  
22 scavenging component of cyclic olefin which does not give off odor and or  
23 taste as a result of its oxygen scavenging function. The oxidation also does  
24 not cause a change in molecular weight. This is because the cyclic olefin  
25 oxygen scavenging component does not fragment as it oxidizes, thus  
26 avoiding the problem of imparting oxidation byproducts to the packaged  
27 material while maintaining the structural integrity.

28

1 It is an object of the present invention to address the foregoing problems or at  
2 least to provide the public with a useful choice.

3

4 Further aspects and advantages of the present invention will become  
5 apparent from the ensuing description, which is given by way of example  
6 only.

7

8 SUMMARY OF INVENTION

9

10 According to one aspect of the present invention, there is provided an oxygen  
11 scavenger for use in or with plastics materials, said scavenger comprising or  
12 including a polymer or oligomer having at least one cyclohexene group or  
13 functionality.

14

15 According to another aspect of the present invention, there is provided an  
16 oxygen scavenger, substantially as described above, which produces only  
17 low levels of volatile or extractable (from a plastics material in which it is  
18 incorporated) products as a consequence of oxygen scavenging.

19

20 According to another aspect of the present invention there is provided an  
21 oxygen scavenger, substantially as described above, which is substantially  
22 stable with respect to reaction with oxygen until triggered by an external  
23 event.

24

25 According to another aspect of the present invention, there is provided an  
26 oxygen scavenger, substantially as described above, wherein the external  
27 event is irradiation by electromagnetic radiation.

28

29 According to a further aspect of the present invention, there is provided an  
30 oxygen scavenging composition, including an oxygen scavenger,

- 1 substantially as described above, which includes one or more trigger
- 2 enhancing components making the scavenger susceptible to triggering from
- 3 an external event.
- 4
- 5 According to another aspect of the present invention, there is provided an
- 6 oxygen scavenging composition, substantially as described above, wherein a
- 7 trigger-enhancing component may be benzophenone or substituted
- 8 derivatives thereof.
- 9
- 10 According to another aspect of the present invention, there is provided an
- 11 oxygen scavenging composition, substantially as described above, which
- 12 includes the presence of one or more catalysts for the scavenging process.
- 13
- 14 According to another aspect of the present invention, there is provided an
- 15 oxygen scavenging composition, substantially as described above, in which a
- 16 catalyst may be a transition metal salt, compound or complex.
- 17
- 18 According to another aspect of the present invention, there is provided an
- 19 oxygen scavenger or oxygen scavenging composition, substantially as
- 20 described above, which is in the form of a plastics resin.
- 21
- 22 According to another aspect of the present invention, there is provided an
- 23 oxygen scavenger or oxygen scavenging composition, substantially as
- 24 described above, in which the plastics resin is a resin suitable for use in the
- 25 manufacture of plastic films.
- 26
- 27 According to another aspect of the present invention, there is provided an
- 28 oxygen scavenger or oxygen scavenging composition, substantially as
- 29 described above, in which the plastic resin is a polyester resin.
- 30

- 1 According to another aspect of the present invention, there is provided an
- 2 oxygen scavenger or oxygen scavenging composition, substantially as
- 3 described above, when present in a plastics film or layer thereof.
- 4
- 5 According to another aspect of the present invention, there is provided an
- 6 oxygen scavenger or oxygen scavenging composition, substantially as
- 7 described above, when used as a polymeric material of a plastics film, a layer
- 8 thereof, and/or a coating thereof, or in a plastics material.
- 9
- 10 According to another aspect of the present invention, there is provided an
- 11 oxygen scavenger or oxygen scavenging composition, substantially as
- 12 described above, when dispersed throughout a plastics film, a layer thereof,
- 13 and/or a coating thereon, or in a plastics material.
- 14
- 15 According to a further aspect of the present invention, there is provided an
- 16 oxygen scavenger or oxygen scavenging composition, substantially as
- 17 described above, in which the anhydride comprises 1,2,3,6-tetrahydrophthalic
- 18 anhydride or tetrahydrophthalic anhydride monomer derivable from
- 19 butadiene.
- 20
- 21 According to a further aspect of the present invention, there is provided an
- 22 oxygen scavenger or oxygen scavenging composition prepared from the
- 23 reaction of a tetrahydrobenzyl alcohol with one or more compounds having
- 24 one or more of the following functionalities: carboxylic acid, acid halide, ester,
- 25 anhydride, and isocyanate.
- 26
- 27 According to another aspect of the present invention, there is provided an
- 28 oxygen scavenger or oxygen scavenging composition, substantially as
- 29 described above, in which the alcohol comprises tetrahydrobenzyl alcohol.
- 30

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1 According to another aspect of the present invention, there is provided an  
2 oxygen scavenger or oxygen scavenging composition, substantially as  
3 described above, in the compounds with which the alcohol is reacted may  
4 include a styrene maleic anhydride copolymer, and/or a polyfunctional  
5 isocyanate.

6

7 According to another aspect of the present invention, there is provided an  
8 oxygen scavenger or oxygen scavenging composition, prepared from a  
9 cyclohexene dimethanol compound.

10

11 According to another aspect of the present invention, there is provided an  
12 oxygen scavenging polymer including at least one pendant cyclohexene  
13 group prepared by a reactive extrusion process.

14

15 According to a further aspect of the present invention, there is provided an  
16 oxygen scavenger or oxygen scavenging polymer, substantially as described  
17 above, in which the reactive extrusion process comprises an esterification or  
18 transesterification step. Suitable catalyst include acids, bases and  
19 organometallic compounds such as the titanium alkoxides.

20

21 According to another aspect of the present invention, there is provided an  
22 oxygen scavenger or oxygen scavenging polymer prepared by a route  
23 including a cyclohexene anhydride.

24

25 According to another aspect of the present invention, there is provided an  
26 oxygen scavenger or oxygen scavenging polymer prepared by a route  
27 including the reaction of a diene monomer, or hydroxy containing monomer,  
28 with a cyclic anhydride.

29

- 1    According to another aspect of the present invention, there is provided an
- 2    oxygen scavenger or oxygen scavenging polymer, substantially as described
- 3    above, in which the cyclic anhydride is a maleic anhydride.
- 4
- 5    According to a further aspect of the present invention, there is provided an
- 6    oxygen scavenger including a pendant cyclic alkene group prepared via a
- 7    method including a Diels Alder addition reaction.
- 8
- 9    According to another aspect of the present invention, there is provided an
- 10   oxygen scavenger, substantially as described above, in which the preferred
- 11   dienes for use in the Diels Alder reaction is substituted and/or unsubstituted
- 12   1,3 butadiene.
- 13   According to another aspect of the present invention, there is provided an
- 14   oxygen scavenger, substantially as described above, in which the preferred
- 15   dienophile for use in the Diels Alder reaction include unsaturated acids,
- 16   anhydrides, and esters.
- 17
- 18   According to another aspect of the present invention, there is provided an
- 19   oxygen scavenger, substantially as described above, in which the cyclic
- 20   alkene is cyclohexene.
- 21
- 22   In other aspects, the present invention provides an article which include at
- 23   least one layer formed from a blend that includes the foregoing composition
- 24   as well as a method of scavenging oxygen in which a packaging article, at
- 25   least one layer of which is formed from a blend that includes the foregoing
- 26   composition, is exposed to actinic or e-beam radiation so as to activate the
- 27   composition.
- 28

- 1 According to a further aspect of the present invention, there is provided an
- 2 oxygen scavenger or oxygen scavenging composition prepared from a
- 3 tetrahydrophthalic anhydride and a polymer or lower molecular weight
- 4 compound containing at least one amine group.
- 5
- 6 According to a further aspect of the present invention, there is provided an
- 7 oxygen scavenger or oxygen scavenging composition prepared from
- 8 diglycidyltetrahydrophthalate.
- 9 According to a further aspect of the present invention, there is provided an
- 10 oxygen scavenger or oxygen scavenging composition prepared from the
- 11 reaction of tetrahydrobenzyl alcohol, methyl or dimethyl substituted
- 12 tetrahydrobenzyl alcohol with one or more compounds having one or more of
- 13 the following functionalities: carboxylic acid, acid halide, ester, anhydride,
- 14 epoxide and isocyanate.
- 15
- 16 According to a further aspect of the present invention, there is provided an
- 17 oxygen scavenger or oxygen scavenging composition, substantially as
- 18 described above, in which a tetrahydrobenzyl alcohol or substituted
- 19 tetrahydrobenzyl alcohol reacts with one or more of the following materials:
- 20
- 21 ethylene (meth)acrylic acid and other acid containing polymers and acid
- 22 containing lower molecular weight materials;
- 23
- 24 styrene maleic anhydride copolymers; alpha olefin maleic anhydride
- 25 copolymers such as octadecene maleic anhydride; ethylene and ethylene
- 26 alpha olefin maleic anhydride terpolymers; ethylene alkyl (meth) acrylate
- 27 maleic anhydride terpolymers and other like anhydride containing polymers or
- 28 anhydride containing lower molecular weight materials;
- 29

- 1 polymeric or lower molecular weight materials containing acid halide
- 2 functionality such as poly acryloyl chloride;
- 3
- 4 ethylene alkyl (meth)acrylate copolymers and terpolymers and alternative
- 5 polymers or lower molecular weight materials containing lower alkyl ester
- 6 functionality;
- 7
- 8 epoxy resins;
- 9
- 10 isocyanate functional material such as prepolymers and oligomers derived
- 11 from the common diisocyanates such as MDI, TDI and the like.
- 12
- 13 According to a further aspect of the present invention, there is provided an
- 14 oxygen scavenger or oxygen scavenging composition prepared from a
- 15 dihydroxy cyclohexene compound. For example, 3 Cyclohexene-1,1-
- 16 dimethanol or its substituted derivatives may be used to prepare polyurethane
- 17 and polyester resins.
- 18
- 19 According to a further aspect of the present invention, there is provided an
- 20 oxygen scavenger or oxygen absorbing composition prepared from a
- 21 cyclohexene carboxylic acid. Such materials may be prepared from acrylic
- 22 acid and substituted and unsubstituted butadienes. A typical example would
- 23 be tetrahydrobenzoic acid, derived from acrylic acid and butadiene. This may
- 24 be reacted with the following materials:
- 25
- 26 hydroxyl functional materials such as poly(vinyl alcohol) and polyethylene-
- 27 vinyl alcohol, hydroxyl functional oligomers such as poly(ethylene glycol), the
- 28 polyester polyols and other lower molecular weight hydroxyl functional
- 29 materials;
- 30

1 amine functional polymers and lower molecular weight compounds;

2

3 polyvalent metal ions.

4

5 According to a further aspect of the present invention, there is provided an  
6 oxygen scavenger prepared from a cyclohexene functional acid chloride.

7 Example 9 utilizes 3-cyclohexene-1-carbonyl chloride.

8

9 According to a further aspect of the present invention, there is provided an  
10 oxygen scavenger or oxygen scavenging composition prepared from  
11 tetrahydrobenzaldehyde and its substituted derivatives. These may be  
12 prepared from reaction of butadiene or the methyl substituted butadienes with  
13 acrolein.

14

15 The tetrahydrobenzaldehydes may be reacted with hydroxyl functional  
16 polymers such as poly(vinyl alcohol) and polyethylene-vinyl alcohol to form  
17 polyvinyl acetals.

18

19 The following definitions apply herein throughout unless a contrary intention is  
20 expressly indicated:

21

22 "polymer" means the polymerization product of one or more monomers and  
23 includes homopolymers, as well as copolymers;

24 "copolymer" means the polymerization product of two or more kinds of  
25 monomers;

26

27 "(meth)acrylate" means acrylate or methacrylate;

28

29 "photoinitiator" means a substance which, when activated by actinic radiation,  
30 enhances and/or facilitates the initiation of one or more properties (e.g.,

1    oxygen scavenging) in another compound, thus resulting in a shorter  
2    induction period and/or an increase in the rate of oxygen uptake of the overall  
3    system;

4

5    "induction period" means the length of time beginning with the initiation of the  
6    active components of a composition and ending with the onset of one or more  
7    useful properties (e.g., oxygen scavenging); and

8

9    "antioxidant" means a material which can inhibit oxidative degradation and/or  
10   crosslinking of a poly polymer so as to, for example, prolong the useful  
11   lifetime of the polymer, to stabilize a polymer-containing composition during  
12   processing (e.g., extrusion, coating, lamination, etc.); and/or to prolong the  
13   shelf-life of the composition (prior to exposure thereof to actinic or e-beam  
14   radiation).

15

16   The present invention is directed to oxygen scavengers. The invention  
17   includes oxygen scavenging substances, as well as compositions containing  
18   same. The form of the oxygen scavengers may vary and may comprise small  
19   molecules through to large macromolecules as well as those sized in  
20   between. The oxygen scavengers will be characterized in that they will be  
21   able to react with oxygen in their near vicinity, enabling the removal of oxygen  
22   from a closed system.

23

24   While the actual form of the oxygen scavengers may vary, a characteristic  
25   that they each share is they include cyclic alkene groups or functionalities,  
26   which are able to react with oxygen to provide the desired oxygen scavenging  
27   properties. In preferred embodiments of the present invention, this will  
28   comprise a cyclohexene group i.e. a six-membered ring with double bond  
29   between two adjacent carbon atoms. It is acceptable that some carbons of

1 the cyclohexene group may also form a part of other ring structures within the  
2 molecule, and/or form part of the skeleton of the molecule. It is not necessary  
3 that the entire C<sub>6</sub> ring be dangling free of the remainder of the molecule to  
4 which it is attached. A consideration however is that the group should be so  
5 positioned and incorporated into the structure that the double bond is  
6 available for reaction with oxygen.

7

8 It has been mentioned above that various scavengers of the present invention  
9 may take different forms. This will also have some bearing on how they are  
10 used, and also produced. Perhaps the simplest embodiments of the present  
11 invention are short molecules containing a reactive cyclohexene group, which  
12 may be dispersed in an appropriate medium for use. This may include the  
13 use of short molecules (see also later) which can be dispersed within a  
14 plastics resin or material. The ultimate result would be a plastics film or  
15 material incorporating the oxygen scavenger. Of course, consideration would  
16 need to be given to accessibility of the scavengers of the oxygen being  
17 scavenged though this may rely on the porosity of the film (or film  
18 layer/material) in which it is incorporated, or alternatively may be presented in  
19 the manner of a coating with a reactive surface.

20

21 While the use of oxygen scavengers of varying sizes, (though typically those  
22 of smaller size), dispersed through plastics materials is envisaged, oxygen  
23 scavengers according to the present invention may also be used in other  
24 ways.

25

26 For instance, they may be dispersed throughout non-plastics materials. This  
27 may include inert and inorganic materials. This may also include other  
28 liquids. It is envisaged that such embodiments of the present invention may  
29 be used in applications such as sachets inserted into closed packages. The

1 use of oxygen scavengers in sachets and package inserts is documented in  
2 the art and the same principles may be applied here.  
3  
4 Another means by which the present invention may be applied is through the  
5 use of plastics resins incorporating the desired scavenging functionalities.  
6 These resins, which for instance may include polyester resins, may be used  
7 in the various manners by which resins are normally used. This may include  
8 film production, resin coatings, as well as molding or extrusion techniques.  
9 Another method by which the present invention may be implemented is the  
10 formation or modification of polymers to contain the desired scavenging  
11 functionalities and groups. In such cases, the film or plastics material itself  
12 will possess oxygen scavenging properties. It is envisaged that such  
13 materials may exist as layers in multi-layer films. Such polymers may also be  
14 introduced as copolymers or blends in film and plastics manufacturing  
15 methods.  
16  
17 The above instances of how embodiments of the present invention may be  
18 used are illustrative only. It is noted that the use of oxygen scavenging  
19 materials is known in the art, and that art may be drawn upon to further  
20 expand the illustrative examples given within this specification.  
21  
22 Embodiments of the present invention based on cyclohexene groups appear  
23 to afford significant advantage over the prior art. This advantage is in the  
24 number and nature of the oxidation product once the scavenging is  
25 completed. In the prior art, heavily reliance is made on straight chain  
26 alkenes, such as for instance fatty acids. The problem however, is that film  
27 containing unsaturated compounds such as squalene or vegetable oils  
28 produce large amounts of volatile aldehydes and ketones upon oxidation.  
29 These tend to be released, or leach, from the plastics material over time,

1 usually find their way into the head space of the packaged material. The  
2 presence of these foreign substances can represent a significant problem,  
3 which the use of cyclohexene scavenging groups addresses at least partially.

4  
5 In comparison, there are significantly less scission products from oxidation  
6 reactions involving cyclohexene groups—the oxidation of the cyclohexene  
7 group does not normally involve ring breakage. If the remainder of the  
8 molecule to which the cyclohexene group is attached is bound or linked to the  
9 polymeric structure of the material in which it is incorporated or affixed, or  
10 otherwise bound or held in place to the material through which it is dispersed  
11 or incorporated, then there is little chance of there being any free scission  
12 products able to find their way from the film or material structure.

13

14 Other aspects of the present invention to some extent parallel the prior art.  
15 For instance, it is desirable that the oxygen scavenging materials are  
16 relatively stable (with respect to scavenging) until required. In many cases,  
17 catalysis and/or triggering of any reaction is required. Photo-initiators such as  
18 benzophenone may be included. Initiating or triggering by electromagnetic  
19 irradiation (often in the visible through UV regions) is convenient form of  
20 triggering and already used in some types of film manufacture. It is also used  
21 for triggering many prior art oxygen scavengers and thus employing these  
22 features and techniques of the prior art with the present invention is  
23 envisaged.

24

25 As for most other oxygen scavengers relying on alkenes, some form of  
26 catalyst is also required for the oxygen scavenging reactions to proceed  
27 effectively. Typically transition metal catalysts are used, including their salts,  
28 complexes, and other compounds. These are well documented in the prior  
29 art and may also be used with the present invention as appropriate.

30

1

2

3 According to another aspect of the present invention, there is provided an  
4 oxygen scavenging polymer, substantially as described above, in which the  
5 reactive extrusion process comprises a transesterification process.

6

7

8

9 According to one aspect of the present invention, there is provided an oxygen  
10 scavenging composition for use in or with plastics materials, said scavenger  
11 comprising or including at least one cyclohexene functionality as described  
12 above.

13

14 According to another aspect of the present invention, there is provided an  
15 oxygen scavenging composition, as described above, which produces only  
16 low levels of volatile or extractable (from a plastics material in which it is  
17 incorporated) products as a consequence of oxygen scavenging.

18

19 According to another aspect of the present invention, there is provided an  
20 oxygen scavenging composition, substantially as described herein which is  
21 substantially stable with respect to reaction with oxygen until triggered by an  
22 external event.

23

24 According to another aspect of the present invention, there is provided an  
25 oxygen scavenging composition, substantially as described above, wherein  
26 the external event is irradiation by actinic radiation or electron beam radiation.

27

28 According to a further aspect of the present invention, there is provided an  
29 oxygen scavenging composition including an oxygen scavenger, substantially

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1 as described above, which includes one or more trigger enhancing  
2 components making the scavenger susceptible to triggering from an external  
3 event.

4

5 According to another aspect of the present invention, there is provided an  
6 oxygen scavenging composition, substantially as described above, wherein a  
7 trigger enhancing component is a photo initiator such as benzophenone or  
8 substituted derivatives thereof.

9

10 According to another aspect of the present invention, there is provided an  
11 oxygen scavenging composition, substantially as described above, which  
12 includes the presence of one or more catalysts for the scavenging process.

13

14 According to another aspect of the present invention, there is provided an  
15 oxygen scavenging composition, substantially as described above, in which  
16 the catalyst is a transition metal salt, compound or complex.

17

18 According to another aspect of the present invention, there is provided an  
19 oxygen scavenging composition, substantially as described above, which is in  
20 the form of a plastic resin.

21

22 According to another aspect of the present invention, there is provided an  
23 oxygen scavenging composition, substantially as described above, in which  
24 the plastic resin is a suitable for use in the manufacture of plastics films.

25

26 According to another aspect of the present invention, there is provided an  
27 oxygen scavenging composition, substantially as described above, in which  
28 the plastic resin is a polyester resin.

29

- 1 According to another aspect of the present invention, there is provided an
- 2 oxygen scavenging article comprising the oxygen scavenging composition
- 3 described above, where the scavenging component is present as a plastic
- 4 film or layer thereof.
- 5
- 6 According to another aspect of the present invention, there is provided an
- 7 oxygen scavenger or oxygen scavenging composition, substantially as
- 8 described above, when used as a polymeric material of a plastic film a layer
- 9 thereof, and/or a coating thereof, or in a plastic material.
- 10
- 11 According to another aspect of the present invention, there is provided an
- 12 oxygen scavenger or oxygen scavenging composition, substantially as
- 13 described above, when dispersed through a plastics film, a layer thereof,
- 14 and/or a coating thereon, or in a plastics material.
- 15
- 16 According to a further aspect of the present invention, there is provided an
- 17 oxygen scavenger or oxygen scavenging composition prepared from the
- 18 reaction of a tetrahydrophthalic anhydride or tetrahydrophthalic acid with at
- 19 least one of a diol, a hydroxy compound or polyhydroxy compound, in the
- 20 presence of or absence of an esterification catalyst.
- 21
- 22 According to a further aspect of the present invention, there is provided an
- 23 oxygen scavenger or oxygen scavenging composition prepared from the
- 24 reaction of a tetrahydrophthalic anhydride or tetrahydrophthalic acid with at
- 25 least one of a diol, a hydroxy compound or polyhydroxy compound , in the
- 26 presence of or absence of an esterification catalyst.
- 27
- 28 According to a further aspect of the present invention there is provided an
- 29 oxygen scavenger or oxygen scavenging composition prepared from an ester

- 1    or diester of a tetrahydrophthalic anhydride, in the presence of or absence of
- 2    a transesterification or esterification catalyst.
- 3
- 4    According to a further aspect of the present invention, there is provided an
- 5    oxygen scavenger or oxygen scavenging composition substantially as
- 6    described above, in which the anhydride comprises 1,2,3,6 tetrahydrophthalic
- 7    anhydride or tetrahydrophthalic anhydride monomers derived from butadiene,
- 8    2,3-Dimethyl-1,3-butadiene or isoprene.
- 9
- 10   According to a further aspect of the present invention, there is provided an
- 11   oxygen scavenging polymer including at least one cyclohexene group
- 12   prepared by a reactive extrusion process.
- 13
- 14   According to the present invention, a composition is provided comprising a
- 15   polymeric backbone, cyclic olefinic pendent groups and linking groups linking
- 16   the olefinic pendent groups to the polymeric backbone.
- 17   Also according to the present invention, an oxygen scavenging composition is
- 18   provided comprising a polymeric backbone, cyclic olefinic pendent groups,
- 19   linking groups linking the olefinic pendent groups to the polymeric backbone
- 20   and a transition metal catalyst.
- 21   Also according to the present invention, an article of manufacture is provided
- 22   which is suitable as a container, the container inhibiting oxidation of contents
- 23   of the container by removing oxygen from the container and by inhibiting
- 24   ingress of oxygen into the container from outside the container, the article
- 25   comprising an oxygen scavenging composition which comprises a polymeric
- 26   backbone, cyclic olefinic pendent groups, linking groups linking the olefinic
- 27   pendent groups to the backbone, and a transition metal catalyst.

1 Also according to the present invention, a layer suitable for scavenging  
2 oxygen is provided which comprises (a) a polymer backbone; (b) cyclic  
3 olefinic pendent groups; (c) linking groups linking the backbone with the  
4 pendent groups; and (d) a transition metal catalyst.

5 Also according to the present invention, a process of making a polymer  
6 material is provided, the process being selected from the group consisting of  
7 esterification, transesterification, amidation, transamidation and direct  
8 polymerization, in which the oxygen scavenging packaging material  
9 comprises a polymer backbone, cyclic olefinic pendent groups, linking groups  
10 linking the backbone with the pendent groups.

11 In a preferred embodiment of the invention, the polymeric backbone of the  
12 above compositions, article, layer and process is ethylenic and the linking  
13 groups are selected from the group consisting of:

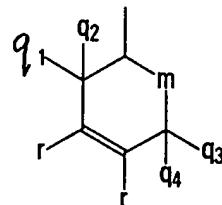
14 -O-(CHR)<sub>n</sub>-; -(C=O)-O-(CHR)<sub>n</sub>-; -NH-(CHR)<sub>n</sub>-; -O-(C=O)-(CHR)<sub>n</sub>-;  
15 -(C=O)-NH-(-CHR)<sub>n</sub>-; and -(C=O)-O-CHOH-CH<sub>2</sub>-O-;  
16 wherein R is hydrogen or an alkyl group selected from the group consisting of  
17 methyl, ethyl, propyl and butyl groups and where n is an integer in the range  
18 from 1 to 12.

19 In a more preferred embodiment of the invention, the cyclic olefinic pendent  
20 groups of the above compositions, article, layer and process have the  
21 structure (II):

22

(II)

23



1

2 where  $q_1$ ,  $q_2$ ,  $q_3$ ,  $q_4$ , and  $r$  are selected from the group consisting of -H, -CH<sub>3</sub>,  
3 and -C<sub>2</sub>H<sub>5</sub>; and where  $m$  is -(CH<sub>2</sub>)<sub>n</sub>- with  $n$  being an integer in the range from 0  
4 to 4; and wherein, when  $r$  is -H, at least one of  $q_1$ ,  $q_2$ ,  $q_3$  and  $q_4$  is -H.

5 In another preferred embodiment of the invention, the polymeric backbone of  
6 the above compositions, article, layer and process comprises monomers  
7 selected from the group consisting of ethylene and styrene.

8 In yet another preferred embodiment of invention, the cyclic olefinic pendent  
9 groups of the above compositions, article, layer and process are grafted onto  
10 the linking groups of the polymeric backbone by a esterification,  
11 transesterification, amidation or transamidation reaction.

12 In still another preferred embodiment of the invention, the esterification,  
13 transesterification, amidation or transamidation reaction of the above  
14 compositions, article, layer and process is a solution reaction or a reactive  
15 extrusion.

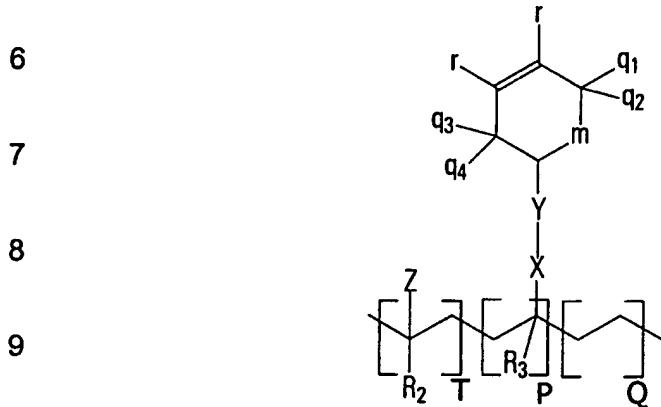
16 In another preferred embodiment of the invention, the esterification,  
17 transesterification, amidation or transamidation reaction of the above  
18 compositions, article, layer and process is catalyzed by a catalyst selected  
19 from the group consisting of strong non-oxidizing acids, tertiary amines,  
20 Group I alkoxides, Group IVB alkoxides, and Group IVA organometallics.

21 In yet another preferred embodiment of invention, the catalyst of the above  
22 compositions, article, layer and process is selected from a group consisting of  
23 toluene sulfonic acid, sodium methoxide, tetrabutyl titanate, tetraisopropyl  
24 titanate, tetra-n-propyl-titanate, tetraethyl titanate, 2-hydroxy-pyridine and  
25 dibutyltin dilaurate.

26

1 In still another preferred embodiment of the invention, the polymeric  
 2 backbone, linking groups and cyclic olefin pendent groups of the above  
 3 compositions, article, layer and process comprise repeating units, each unit  
 4 having a structure (III) as follows:

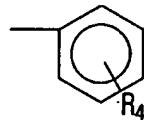
5 (III)



12 al composition; Z is selected from the group consisting of an aryl group;  
 13 -(C=O)OR<sub>1</sub>; -O(C=O)R<sub>1</sub>; and an alkyl aryl group, structure (IV):

14 (IV)

15



16 where R<sub>4</sub> is selected from the group consisting of -CH<sub>3</sub>, -C<sub>2</sub>H<sub>5</sub>, and -H; R<sub>1</sub> is  
 17 selected from the group consisting of -H, -CH<sub>3</sub>, -C<sub>2</sub>H<sub>5</sub>, -C<sub>3</sub>H<sub>7</sub> and -C<sub>4</sub>H<sub>9</sub>; R<sub>2</sub> and  
 18 R<sub>3</sub> are selected from the group consisting of -H and -CH<sub>3</sub>; X is selected from  
 19 the group consisting of -O-, -NH-, -(C=O)O-, -(C=O)NH-, -(C=O)S-, -O(C=O)-  
 20 and -(CHR)<sub>l</sub>-, l is an integer in the range from 1 to 6; Y is -(CHR)<sub>n</sub>-, where n is  
 21 an integer in the range from 0 to 12, R being selected from the group  
 22 consisting of -H, -CH<sub>3</sub> and -C<sub>2</sub>H<sub>5</sub>; where q<sub>1</sub>, q<sub>2</sub>, q<sub>3</sub>, q<sub>4</sub>, and r are selected from  
 23 the group consisting of -H, -CH<sub>3</sub>, and -C<sub>2</sub>H<sub>5</sub>; and where m is -(CH<sub>2</sub>)<sub>n</sub>- and

- 1 where n is an integer in the range from 0 to 4; and wherein when r is -H, at
- 2 least one of q<sub>1</sub>, q<sub>2</sub>, q<sub>3</sub> and q<sub>4</sub> is -H.
  
- 3 In another preferred embodiment of the invention, the cyclic olefinic pendent
- 4 groups of the above compositions, article, layer and process are selected
- 5 from the group consisting of cyclohexene-4-methylene radical, 1-methyl
- 6 cyclohexene-4-methylene radical, 2-methyl cyclohexene-4-methylene radical,
- 7 5-methyl cyclohexene-4-methylene radical, 1,2-dimethyl cyclohexene-4-
- 8 methylene radical, 1,5-dimethyl cyclohexene-4-methylene radical,
- 9 2,5-dimethyl cyclohexene-4-methylene radical, 1,2,5-trimethyl cyclohexene-4-
- 10 methylene radical, cyclohexene-4-ethylene radical, 1-methyl cyclohexene-4-
- 11 ethylene radical, 2-methyl cyclohexene-4-ethylene radical, 5-methyl
- 12 cyclohexene-4-ethylene radical, 1,2-dimethyl cyclohexene-4-ethylene radical,
- 13 1,5-dimethyl cyclohexene-4-ethylene radical, 2,5-dimethyl cyclohexene-4-
- 14 ethylene radical, 1,2,5-trimethyl cyclohexene-4-ethylene radical, cyclohexene-
- 15 4-propylene radical, 1-methyl cyclohexene-4-propylene radical, 2-methyl
- 16 cyclohexene-4-propylene radical, 5-methyl cyclohexene-4-propylene radical,
- 17 1,2-dimethyl cyclohexene-4-propylene radical, 1,5-dimethyl cyclohexene-4-
- 18 propylene radical, 2,5-dimethyl cyclohexene-4-propylene radical,
- 19 1,2,5-trimethyl cyclohexene-4-propylene radical, cyclopentene-4-methylene
- 20 radical, 1-methyl cyclopentene-4-methylene radical, 3-methyl cyclopentene-4-
- 21 methylene radical, 1,2-dimethyl cyclopentene-4-methylene radical,
- 22 3,5-dimethyl cyclopentene-4-methylene radical, 1,3-dimethyl cyclopentene-4-
- 23 methylene radical, 2,3-dimethyl cyclopentene-4-methylene radical,
- 24 1,2,3-trimethyl cyclopentene-4-methylene radical, 1,2,3,5-tetramethyl
- 25 cyclopentene-4-methylene radical, cyclopentene-4-ethylene radical, 1-methyl
- 26 cyclopentene-4-ethylene radical, 3-methyl cyclopentene-4-ethylene radical,
- 27 1,2-dimethyl cyclopentene-4-ethylene radical, 3,5-dimethyl cyclopentene-4-
- 28 ethylene radical, 1,3-dimethyl cyclopentene-4-ethylene radical, 2,3-dimethyl
- 29 cyclopentene-4-ethylene radical, 1,2,3-trimethyl cyclopentene-4-ethylene

- 1 radical, 1,2,3,5-tetramethyl cyclopentene-4-ethylene radical, cyclopentene-4-
- 2 propylene radical, 1-methyl cyclopentene-4-propylene radical, 3-methyl
- 3 cyclopentene-4-propylene radical, 1,2-dimethyl cyclopentene-4-propylene
- 4 radical, 3,5-dimethyl cyclopentene-4-propylene radical, 1,3-dimethyl
- 5 cyclopentene-4-propylene radical, 2,3-dimethyl cyclopentene-4-propylene
- 6 radical, 1,2,3-trimethyl cyclopentene-4-propylene radical, and
- 7 1,2,3,5-tetramethyl cyclopentene-4-propylene radical.
  
- 8 In yet another preferred embodiment of the invention, the composition of the
- 9 above compositions, article, layer and process is a ethylene/methyl
- 10 acrylate/cyclohexenyl methyl acrylate terpolymer, a cyclohexenyl methyl
- 11 acrylate/ethylene copolymer, a cyclohexenyl methyl methacrylate/styrene
- 12 copolymer, a cyclohexenyl methyl acrylate homopolymer or a methyl
- 13 acrylate/cyclohexenyl methyl acrylate copolymer.
  
- 14
- 15 In another preferred embodiment of the invention, the odor and taste
- 16 characteristics of products packaged with material comprised of the above
- 17 compositions, article, layer and process are not adulterated as a result of
- 18 oxidation of the composition.
  
- 19
- 20 In still another preferred embodiment of the invention, there is no significant
- 21 fragmentation of the olefinic pendent groups and linking groups from the
- 22 polymeric backbone as a result of oxidation of the above compositions,
- 23 article, layer and process.
  
- 24
- 25 In yet another preferred embodiment of the invention, the transition metal
- 26 catalyst of the above oxygen scavenging composition, article of manufacture,
- 27 layer and process is a metal salt.
  
- 28

- 1 In still another preferred embodiment of the invention, the metal in the metal
- 2 salt of the above oxygen scavenging composition, article of manufacture,
- 3 layer and process is cobalt.
- 4 In still another preferred embodiment of the invention, the metal salt of the
- 5 above oxygen scavenging composition, article of manufacture, layer and
- 6 process is selected from the group consisting of cobalt neodecanoate, cobalt
- 7 2-ethylhexanoate, cobalt oleate and cobalt stearate.
- 8
- 9 In yet another preferred embodiment of the invention, the composition of the
- 10 above oxygen scavenging composition, article of manufacture, layer and
- 11 process further comprises at least one triggering material to enhance initiation
- 12 of oxygen scavenging.
- 13
- 14 In still another preferred embodiment of the invention, the triggering material
- 15 of the above oxygen scavenging composition, article of manufacture, layer
- 16 and process is a photo initiator.
- 17
- 18 In a preferred embodiment of the invention, the above article of manufacture
- 19 is a package.
- 20
- 21 In another preferred embodiment of invention, the package article of the
- 22 above article of manufacture comprises a flexible film having a thickness of at
- 23 most 10 mil or a flexible sheet having a thickness of at least 10 mil.
- 24
- 25 In yet another preferred embodiment of the invention, the oxygen scavenging
- 26 system of the package article of the above article of manufacture comprises
- 27 at least one additional layer selected from among oxygen barrier layers,
- 28 polymeric selective layers, and heat seal layers.
- 29

- 1 In still another preferred embodiment of the invention, the above article of
- 2 manufacture is a package with a food product located within the package.
- 3 In yet another preferred embodiment of the invention, the above article of
- 4 manufacture is a package for packaging a cosmetic, chemical, electronic
- 5 device, pesticide or a pharmaceutical composition.
- 6
- 7 In still another preferred embodiment of the invention, a multi-layer film
- 8 comprises the article of the above article of manufacture and the film has at
- 9 least one additional functional layer.
- 10
- 11 In yet another preferred embodiment of the invention, the multi-layer film of
- 12 the above article of manufacture has at least one additional layer selected
- 13 from among oxygen barrier layers, polymeric selective barrier layers,
- 14 structural layers and heat seal layers.
- 15
- 16 In still another preferred embodiment of the invention, the multi-layer film of
- 17 the above article of manufacture has at least one additional layer which is an
- 18 oxygen barrier layer.
- 19
- 20 In yet another preferred embodiment of the invention, the multi-layer film of
- 21 the above article of manufacture further comprises at least one polymeric
- 22 selective barrier layer.
- 23
- 24 In still another preferred embodiment of the invention, the multi-layer film of
- 25 the above article of manufacture further comprises at least one heat seal
- 26 layer.
- 27
- 28 In yet another preferred embodiment of the invention, the multi-layer film of
- 29 the above article of manufacture further comprises at least one structural
- 30 layer.

-40-

- 1 In still another preferred embodiment of the invention, the above article of manufacture is a rigid container, sealing gasket, patch, container closure device, bottle cap, bottle cap insert or molded or thermoformed shape.
- 4
- 5 In yet another preferred embodiment of the invention, the molded or
- 6 thermoformed shape of the above article of manufacture is a bottle or tray.
- 7
- 8 In still another preferred embodiment of the invention, the above layer in
- 9 addition comprises polymeric diluent.
- 10
- 11 In yet another preferred embodiment of the invention, the diluent of the above
- 12 layer is a thermoplastic polymer.
- 13
- 14 In still another preferred embodiment of the invention, the above layer is
- 15 adjacent to one or more additional layers.
- 16
- 17 In still another preferred embodiment of the invention, at least one of the
- 18 additional layers adjacent to the above layer is an oxygen barrier.
- 19
- 20 In still another preferred embodiment of the invention, the oxygen barrier of
- 21 the above layer comprises a member of the group consisting of poly(ethylene-
- 22 vinyl alcohol), polyacrylonitrile, poly(vinyl chloride), polyamides,
- 23 poly(vinylidene dichloride), poly(ethylene terephthalate), silica, metal foil and
- 24 metalized polymeric films.
- 25
- 26 In still another preferred embodiment of the invention, the one or more of said
- 27 additional layer or layers of the above layer is coextruded with the above
- 28 layer.
- 29

- 1    In yet another preferred embodiment of the invention, the one or more of said
- 2    additional layer or layers of the above layer is laminated onto the above layer.
- 3
- 4    In still another preferred embodiment of the invention, the one or more of said
- 5    additional layer or layers of the above layer is coated onto the above layer.
- 6
- 7    In yet another preferred embodiment of the invention, the above layer is
- 8    flexible.
- 9
- 10   In still another preferred embodiment of the invention, the above layer is
- 11   transparent.
- 12
- 13   In yet another preferred embodiment of the invention, an article for packaging
- 14   wherein the article comprises the above layer.
- 15
- 16   In yet another preferred embodiment of the invention, the above process of
- 17   making the oxygen scavenging packaging material comprises the steps of:
- 18   (a) selecting polymers from the group consisting of styrene/maleic
- 19   anhydride, ethylene/maleic anhydride, ethylene/acrylic acid,
- 20   ethylene/methacrylic acid, acrylic acid, methacrylic acid,
- 21   styrene/methacrylic acid, ethylene/methyl acrylate, ethylene/ethyl
- 22   acrylate, ethylene/butyl acrylate, methyl methacrylate, methyl acrylate,
- 23   and styrene/methyl methacrylate to form a mixture and combining the
- 24   polymers with an esterifying/transesterifying compound selected from
- 25   the group consisting of cyclohexene-4-methanol, 1-methyl cyclohexene-
- 26   4-methanol, 2-methyl cyclohexene-4-methanol, 5-methyl cyclohexene-4-
- 27   methanol, 1,2-dimethyl cyclohexene-4-methanol, 1,5-dimethyl
- 28   cyclohexene-4-methanol, 2,5-dimethyl cyclohexene-4-methanol,

1        1,2,5-trimethyl cyclohexene-4-methanol, cyclohexene-4-ethanol,  
2        1-methyl cyclohexene-4-ethanol, 2-methyl cyclohexene-4-ethanol,  
3        5-methyl cyclohexene-4-ethanol, 1,2-dimethyl cyclohexene-4-ethanol,  
4        1,5-dimethyl cyclohexene-4-ethanol, 2,5-dimethyl cyclohexene-4-  
5        ethanol, 1,2,5-trimethyl cyclohexene-4-ethanol, cyclohexene-4-propanol,  
6        1-methyl cyclohexene-4-propanol, 2-methyl cyclohexene-4-propanol,  
7        5-methyl cyclohexene-4-propanol, 1,2-dimethyl cyclohexene-4-propanol,  
8        1,5-dimethyl cyclohexene-4-propanol, 2,5-dimethyl cyclohexene-4-  
9        propanol, 1,2,5-trimethyl cyclohexene-4-propanol, cyclopentene-4-  
10      methanol, 1-methyl cyclopentene-4-methanol, 3-methyl cyclopentene-4-  
11      methanol, 1,2-dimethyl cyclopentene-4-methanol, 3,5-dimethyl  
12      cyclopentene-4-methanol, 1,3-dimethyl cyclopentene-4-methanol,  
13      2,3-dimethyl cyclopentene-4-methanol, 1,2,3-trimethyl cyclopentene-4-  
14      methanol, 1,2,3,5-tetramethyl cyclopentene-4-methanol, cyclopentene-  
15      4-ethanol, 1-methyl cyclopentene-4-ethanol, 3-methyl cyclopentene-4-  
16      ethanol, 1,2-dimethyl cyclopentene-4-ethanol, 3,5-dimethyl  
17      cyclopentene-4-ethanol, 1,3-dimethyl cyclopentene-4-ethanol,  
18      2,3-dimethyl cyclopentene-4-ethanol, 1,2,3-trimethyl cyclopentene-4-  
19      ethanol, 1,2,3,5-tetramethyl cyclopentene-4-ethanol, cyclopentene-4-  
20      propanol, 1-methyl cyclopentene-4-propanol, 3-methyl cyclopentene-4-  
21      propanol, 1,2-dimethyl cyclopentene-4-propanol, 3,5-dimethyl  
22      cyclopentene-4-propanol, 1,3-dimethyl cyclopentene-4-propanol,  
23      2,3-dimethyl cyclopentene-4-propanol, 1,2,3-trimethyl cyclopentene-4-  
24      propanol, and 1,2,3,5-tetramethyl cyclopentene-4-propanol;

25      (b) heating the polymers and esterifying/transesterifying compounds  
26      selected in (a) to form a polymer melt;

27      (c) processing the melt in an extruder under esterification/transesterification  
28      conditions with esterification/transesterification catalysts and

1       antioxidants protecting the melt from oxidation during extrusion, so that  
2       the polymer melt undergoes esterification of polymeric anhydrides with  
3       cyclic olefin pendent groups, esterification of polymeric acids with cyclic  
4       olefin pendent groups or exchange of alkyl groups of polymeric esters  
5       with cyclic olefin pendent groups; and

6       (d) removing volatile organic products and by-products from the melt.

7       In still another preferred embodiment of the invention, the above process of  
8       making the oxygen scavenging packaging material comprises the steps of:

9       (a) selecting polymers from the group consisting of styrene/maleic  
10      anhydride, ethylene/maleic anhydride, ethylene/acrylic acid,  
11      ethylene/methacrylic acid, acrylic acid, methacrylic acid,  
12      styrene/methacrylic acid, ethylene/methyl acrylate, ethylene/ethyl  
13      acrylate, ethylene/butyl acrylate, methyl methacrylate, methyl acrylate,  
14      and styrene/methyl methacrylate to form a mixture and combining the  
15      polymers with an amidizing/transamidizing compound selected from the  
16      group consisting of cyclohexene-4-methyl amine, 1-methyl cyclohexene-  
17      4-methyl amine, 2-methyl cyclohexene-4-methyl amine, 5-methyl  
18      cyclohexene-4-methyl amine, 1,2-dimethyl cyclohexene-4-methyl amine,  
19      1,5-dimethyl cyclohexene-4-methyl amine, 2,5-dimethyl cyclohexene-4-  
20      methyl amine, 1,2,5-trimethyl cyclohexene-4-methyl amine,  
21      cyclohexene-4-ethyl amine, 1-methyl cyclohexene-4-ethyl amine,  
22      2-methyl cyclohexene-4-ethyl amine, 5-methyl cyclohexene-4-ethyl  
23      amine, 1,2-dimethyl cyclohexene-4-ethyl amine, 1,5-dimethyl  
24      cyclohexene-4-ethyl amine, 2,5-dimethyl cyclohexene-4-ethyl amine,  
25      1,2,5-trimethyl cyclohexene-4-ethyl amine, cyclohexene-4-propyl amine,  
26      1-methyl cyclohexene-4-propyl amine, 2-methyl cyclohexene-4-propyl  
27      amine, 5-methyl cyclohexene-4-propyl amine, 1,2-dimethyl cyclohexene-  
28      4-propyl amine, 1,5-dimethyl cyclohexene-4-propyl amine, 2,5-dimethyl

1        cyclohexene-4-propyl amine, 1,2,5-trimethyl cyclohexene-4-propyl  
2        amine, cyclopentene-4-methyl amine, 1-methyl cyclopentene-4-methyl  
3        amine, 3-methyl cyclopentene-4-methyl amine, 1,2-dimethyl  
4        cyclopentene-4-methyl amine, 3,5-dimethyl cyclopentene-4-methyl  
5        amine, 1,3-dimethyl cyclopentene-4-methyl amine, 2,3-dimethyl  
6        cyclopentene-4-methyl amine, 1,2,3-trimethyl cyclopentene-4-methyl  
7        amine, 1,2,3,5-tetramethyl cyclopentene-4-methyl amine, cyclopentene-  
8        4-ethyl amine, 1-methyl cyclopentene-4-ethyl amine, 3-methyl  
9        cyclopentene-4-ethyl amine, 1,2-dimethyl cyclopentene-4-ethyl amine,  
10       3,5-dimethyl cyclopentene-4-ethyl amine, 1,3-dimethyl cyclopentene-4-  
11       ethyl amine, 2,3-dimethyl cyclopentene-4-ethyl amine, 1,2,3-trimethyl  
12       cyclopentene-4-ethyl amine, 1,2,3,5-tetramethyl cyclopentene-4-ethyl  
13       amine, cyclopentene-4-propyl amine, 1-methyl cyclopentene-4-propyl  
14       amine, 3-methyl cyclopentene-4-propyl amine, 1,2-dimethyl  
15       cyclopentene-4-propyl amine, 3,5-dimethyl cyclopentene-4-propyl  
16       amine, 1,3-dimethyl cyclopentene-4-propyl amine, 2,3-dimethyl  
17       cyclopentene-4-propyl amine, 1,2,3-trimethyl cyclopentene-4-propyl  
18       amine, and 1,2,3,5-tetramethyl cyclopentene-4-propyl amine;

19       (b) heating the polymers and amidizing/transamidizing compounds selected  
20       in (a) to form a polymer melt;

21       (c) processing the melt in an extruder under amidation/transamidation  
22       conditions with amidation/transamidation catalysts and antioxidants  
23       protecting the melt from oxidation during extrusion, so that the polymer  
24       melt undergoes amidation of polymeric anhydrides with cyclic olefin  
25       pendent groups, amidation of polymeric acids with cyclic olefin pendent  
26       groups or exchange of alkyl groups of polymeric esters with cyclic olefin  
27       pendent groups; and

28       (d) removing volatile organic products and by-products from the melt.

- 1    In yet another preferred embodiment of the invention, the above process of
- 2    making of the oxygen scavenging packaging material comprises the steps of:
- 3    (a) adding to an autoclave, ethylene and a vinyl monomer comprising a
- 4       pendent cyclohexene;
- 5
- 6    (b) stirring the ethylene and the vinyl monomer in the autoclave to achieve a
- 7       mixture;
- 8
- 9    (c) adding a polymerization initiator before, during or after the stirring step;
- 10
- 11   (d) polymerizing the mixture to achieve a polymer; and
- 12
- 13   (e) isolating and purifying the polymer.
- 14
- 15   In still another embodiment of the invention, in the above process, in step (a),
- 16   an alpha-olefin is added to the autoclave along with the ethylene and the vinyl
- 17   monomer and, in step (b), the alpha-olefin is stirred with the ethylene and the
- 18   vinyl monomer to achieve the mixture.
- 19
- 20   The present invention relates to a non-odorous oxygen scavenging polymer
- 21   composition comprising: (1) monomers derived from cyclic hydrocarbon
- 22   moieties having at least one cyclic allylic or cyclic benzylic hydrogen and (2) a
- 23   transition metal oxidation catalyst. The present invention also relates to a
- 24   rigid container for food or beverage, the container being molded from a resin
- 25   comprising the above-described non-odorous oxygen scavenging polymer
- 26   composition. The present invention also relates to the above-described rigid
- 27   container further comprising a tinted ultraviolet protection layer, which may or
- 28   may not be the food contact layer, located between the layer comprising the
- 29   non-odorous oxygen scavenging composition and the inside of the rigid
- 30   container.

- 1 In a preferred embodiment of the above non-odorous oxygen scavenging
- 2 polymer composition, wherein the composition comprises a vinyl polymer
- 3 selected from the group consisting of ethylene polymer, ethylene copolymer,
- 4 propylene polymer, propylene copolymer, styrene polymer, styrene copolymer
- 5 and mixtures thereof.
- 6
- 7 In another preferred embodiment of the above non-odorous oxygen
- 8 scavenging polymer composition, the composition comprises condensation
- 9 polymers selected from the group consisting of polyesters, polyamides,
- 10 polycarbonate, polyurethane, polyureas and polyether.
- 11
- 12 In a more preferred embodiment of the above composition comprising
- 13 condensation polymers, the composition is thermoplastic.
- 14
- 15 In another more preferred embodiment of the above composition comprising
- 16 condensation polymers, the composition is thermoset.
- 17
- 18 In yet another more preferred embodiment of the above composition
- 19 comprising condensation polymers, the composition is a multilayered
- 20 structure with other layers being an aromatic polyester or copolyester
- 21 selected from the group consisting of polyethylene terephthalate,
- 22 polyethylene naphthalate, polypropylene terephthalate, polybutylene
- 23 terephthalate, polyethylene isophthalate, polycyclohexanedimethanol
- 24 terephthalate, polybutylene naphthalate, polycyclohexanedimethanol
- 25 naphthalate, and copolymers and blends thereof.
- 26
- 27 In still another more preferred embodiment of the above composition
- 28 comprising condensation polymers, the composition is a multilayered
- 29 structure with other layers being polyamides or copolyamides selected from
- 30 the group consisting of Nylon 6, Nylon 66, Nylon 610 and mixtures thereof.

- 1 In yet another more preferred embodiment of the above composition
- 2 comprising condensation polymers, the composition is a multilayered
- 3 structure with other layers being bisphenol A carbonate.
- 4
- 5 In yet another more preferred embodiment of the above composition
- 6 comprising condensation polymers, the composition is a multilayered
- 7 structure with other layers being vinylic polymers or copolymers selected
- 8 from the group consisting of ethylene polymer, ethylene copolymer, propylene
- 9 polymer, propylene copolymer, styrene polymer, styrene copolymer, acrylate
- 10 polymer, acrylate copolymer, vinyl chloride polymer, vinyl chloride copolymer,
- 11 divinyl chloride polymer, divinyl chloride copolymer, fluorinated vinyl polymer,
- 12 fluorinated vinyl copolymer and mixtures thereof.
- 13
- 14 In still another more preferred embodiment of the above composition
- 15 comprising condensation polymers, the composition is blended with an
- 16 aromatic polyester or copolyester selected from the group consisting of
- 17 polyethylene terephthalate, polyethylene naphthalate, polypropylene
- 18 terephthalate, polybutylene terephthalate, polyethylene isophthalate,
- 19 polycyclohexanedimethanol terephthalate, polybutylene naphthalate,
- 20 polycyclohexanediethanol naphthalate, and copolymers and blends thereof.
- 21
- 22 In yet another more preferred embodiment of the above composition
- 23 comprising condensation polymers, the composition is blended with
- 24 polyamides or copolyamides selected from the group consisting of Nylon 6,
- 25 Nylon 66, Nylon 610 and mixtures thereof.
- 26
- 27 In still another more preferred embodiment of the above composition
- 28 comprising condensation polymers, the composition is blended with bisphenol
- 29 A polycarbonate.

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1 In yet another more preferred embodiment of the above composition  
 2 comprising condensation polymers, the composition being a blend comprising  
 3 vinylic polymers or copolymers selected from the group consisting of ethylene  
 4 polymer, ethylene copolymer, propylene polymer, propylene copolymer,  
 5 styrene polymer, styrene copolymer, acrylate polymer, acrylate copolymer,  
 6 vinyl chloride polymer, vinyl chloride copolymer, divinyl chloride polymer,  
 7 divinyl chloride copolymer, fluorinated vinyl polymer, fluorinated vinyl  
 8 copolymer and mixtures thereof.

9

10 In a more preferred embodiment of the above composition comprising  
 11 condensation polymers, the composition is laminated or adhering onto a  
 12 substrate selected from the group consisting of paper, foil, high temperature  
 13 film, metallized film, polyamide films, ethylene vinyl alcohol film, silica coated  
 14 film, nylon/EVOH/nylon, oriented polypropylene, polyester film, polyethylene,  
 15 polypropylene, polyester, oriented polyethylene terephthalate and cellophane.

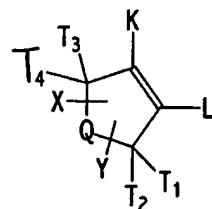
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17 In another preferred embodiment of the above non-odorous oxygen  
 18 scavenging polymer composition, the cyclic allylic monomers are selected  
 19 from the group consisting of structure (V), structure (VI) and structure (VII):

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(V)



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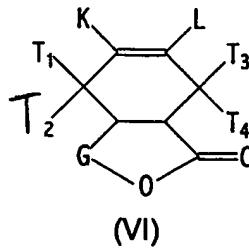
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(VI)

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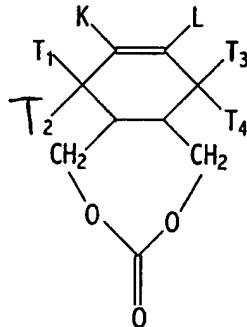
12 with K, L, T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> being selected from the group consisting of  
 13 -C<sub>q</sub>H<sub>2q+1</sub> with q being an integer in the range from 0 to 12 and wherein,  
 14 when either K or L is -H, at least one of T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> is -H;  
 15 and with X and Y being selected from the group consisting of -(CH<sub>2</sub>)<sub>n</sub>-  
 16 OH, -(CH<sub>2</sub>)<sub>n</sub>-NH<sub>2</sub>, -(CH<sub>2</sub>)<sub>n</sub>NC=O and -(CH<sub>2</sub>)<sub>m</sub>-(C=O)-A with n being an  
 17 integer in the range from 1 to 12 and m being an integer in the range  
 18 from 0 to 12 and A being selected from the group consisting of -OH,  
 19 -OCH<sub>3</sub>, -OC<sub>2</sub>H<sub>5</sub>, -OC<sub>3</sub>H<sub>7</sub>, and halides; and Q being selected from the  
 20 group consisting of -(C<sub>t</sub>H<sub>2t-2</sub>) with t being an integer in the range from 1  
 21 to 4;  
 22 and with G being selected from -(C=O)- and -(C<sub>n</sub>H<sub>2n+1</sub>)- with n being an  
 23 integer from 0 to 12.

24

25 In yet another more preferred embodiment of the above non-odorous oxygen  
 26 scavenging polymer composition, the cyclic benzylic monomers are selected  
 27 from the group consisting of structure (VIII), structure (IX), structure (X),  
 28 structure (XI), structure (XII), and structure (XIII)

29

30



(VII)

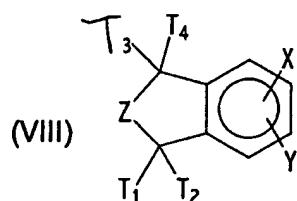
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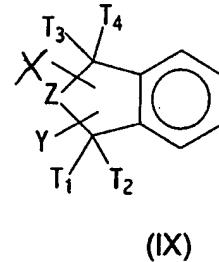
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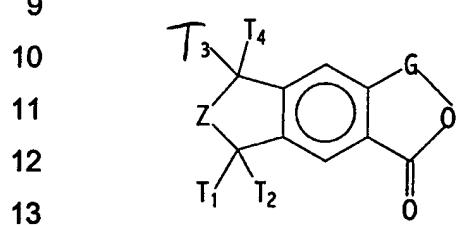
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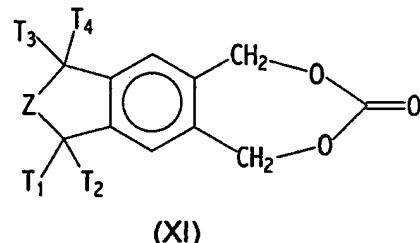
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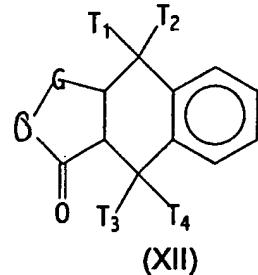
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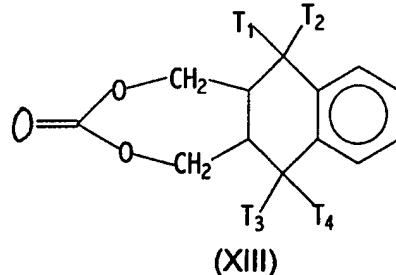
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28

29 where X and Y are selected from the group consisting of  $-(CH_2)_n-OH$ ,

30  $-(CH_2)_n-NH_2$  and  $-(CH_2)_m-(C=O)-R$ , with n being an integer in the range



1       from 1 to 12, and with m being an integer in the range from 0 to 12 and  
2       with R<sub>1</sub> being selected from the group consisting of -OH, -OCH<sub>3</sub>,  
3       -OC<sub>2</sub>H<sub>5</sub>, -OC<sub>3</sub>H<sub>7</sub> and halides;  
4       with T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> being selected from the group consisting of  
5       -C<sub>q</sub>H<sub>2q+1</sub> with q being an integer in the range from 0 to 12 and at least  
6       one of T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> being -H;  
7       and with X and Y being selected from the group consisting of -  
8       (CH<sub>2</sub>)<sub>n</sub>-OH, -(CH<sub>2</sub>)<sub>n</sub>-NH<sub>2</sub>, -(CH<sub>2</sub>)<sub>n</sub>NC=O, and -(CH<sub>2</sub>)<sub>m</sub>-(C=O)-A with n  
9       being an integer in the range from 1 to 12, and m being an integer in the  
10      range from 0 to 12 and A being selected from the group consisting of  
11      -OH, -OCH<sub>3</sub>, -OC<sub>2</sub>H<sub>5</sub>, -OC<sub>3</sub>H<sub>7</sub> and halides; and Z being selected from the  
12      group consisting of -(C<sub>t</sub>H<sub>2t+2</sub>)-, -O-, -NR<sub>2</sub>-, -S-, with t being an integer in  
13      the range from 1 to 4 and R<sub>2</sub> being selected from the group consisting of  
14      -OH, -OCH<sub>3</sub>, -OC<sub>2</sub>H<sub>5</sub>, -OC<sub>3</sub>H<sub>7</sub> and halides;  
15      and with G being selected from -(C=O)- and -(C<sub>n</sub>H<sub>2n+1</sub>)- with n being an  
16      integer from 0 to 12.

17     In still another more preferred embodiment, the composition of the resin of the  
18     above-described rigid container is a single layer.

19

20     In yet another more preferred embodiment, the composition of the resin of the  
21     above-described rigid container is multilayered.

22

23     In yet another more preferred embodiment, the composition of the resin of the  
24     above-described rigid container comprises an outer air contact layer and an  
25     inner oxygen scavenging layer.

26

27     In still another more preferred embodiment, the outer air contact layer of the  
28     composition of the resin of the above-described rigid container comprises an  
29     oxygen barrier resin selected from the group consisting of polyethylene

- 1 terephthalate, polyethylene naphthalate and a mixture of polyethylene
- 2 terephthalate and polyethylene naphthalate.
- 3
- 4 In yet another more preferred embodiment, the composition of the resin of the
- 5 above-described rigid container further comprises at least one of an inner
- 6 food contact layer, a tie layer, and a tinted ultraviolet protection layer.
- 7
- 8 In still another more preferred embodiment, the inner food contact layer of the
- 9 composition of the resin of the above-described rigid container comprises an
- 10 oxygen barrier resin selected from the group consisting of polyethylene
- 11 terephthalate, polyethylene naphthalate and a mixture of polyethylene
- 12 terephthalate and polyethylene naphthalate.
- 13
- 14 In yet another more preferred embodiment, the oxygen scavenging of the
- 15 composition of the resin of the above-described rigid container is initiated by
- 16 moisture or actinic radiation.
- 17 In still another more preferred embodiment, the transition metal catalyst of the
- 18 composition of the resin of the above-described rigid container is a metal salt.
- 19
- 20 In yet another more preferred embodiment, the metal in the metal salt of the
- 21 transition metal catalyst of the composition of the resin of the above-
- 22 described rigid container is cobalt.
- 23
- 24 In still another more preferred embodiment, the metal salt of the transition
- 25 metal catalyst of the composition of the resin of the above-described rigid
- 26 container is selected from the group consisting of cobalt neodecanoate,
- 27 cobalt 2-ethylhexanoate, cobalt oleate and cobalt stearate.
- 28

1 In yet another more preferred embodiment, the composition of the resin of the  
2 above-described rigid container further comprises at least one triggering  
3 material to enhance initiation of oxygen scavenging.

4

5 In still another more preferred embodiment, the triggering material of the resin  
6 of the composition of the above-described rigid container is a photoinitiator.

7

8 In yet another more preferred embodiment, the photoinitiator of the resin of  
9 the composition of the above-described rigid container has an ultraviolet  
10 absorption window above 320 nm.

11

12 In still another more preferred embodiment, the above-described rigid  
13 container is suitable for packaging oxygen sensitive drinks for extended  
14 freshness and shelf life.

15

16 In yet another more preferred embodiment, the above-described rigid  
17 container is suitable for packaging beer.

18

19 DESCRIPTION OF THE DRAWINGS

20 Figure 1 is a schematic showing the overall process leading to the  
21 transesterification of ethylene methyl acrylate copolymers (EMAC) to give  
22 modified EMAC having cyclic pendent olefins.

23 Figure 2 is a graph comparatively plotting percent oxygen in headspace at  
24 4°C (initially at 1% oxygen) against time in days for two 3-layer film extrusions  
25 based on Dowlex® 3010/EMCM/Dowlex® 3010 films (EMCM being an  
26 acronym for ethylene/methyl acrylate/cyclohexenyl methyl acrylate terpolymer  
27 also referred to as poly(ethylene/methyl acrylate/cyclohexene-methyl  
28 acrylate)), both including the EMCM inner layer and one of them having

-54-

- 1 50 ppm of a non-volatile antioxidant Irganox® 1010 in the EMCM layer and
- 2 one of them having 100 ppm Irganox® 1010 in the EMCM layer.
  
- 3 Figure 3 is a graph comparatively plotting percent oxygen in headspace at
- 4 4°C (initially at 1% oxygen) against time in days for an EMCM film and two
- 5 EBAC blended EMCM films, one of them having 3:1 EBAC:EMCM and one of
- 6 them having 1:1 EBAC:EMCM.
  
- 7 Figure 4 is a graph comparatively plotting the oxygen scavenging rates and
- 8 capacities at 25°C in which the initial headspace oxygen was 21% (air) for an
- 9 EMCM film and a 2:1 EBAC:EMCM film.
  
- 10 Figure 5 is a graph showing the taste ratings in a comparative taste test
- 11 between food stored in two oxygen scavenging packages (EMCM and SBS)
- 12 and a control package (no oxygen scavenger).

13

14

15

16 DETAILED DESCRIPTION OF THE INVENTION

17

18 We have found that materials containing certain cyclohexenyl functionalities

19 are excellent oxygen absorbers when compounded with a transition metal salt

20 and optionally a photoinitiator, and that when these materials oxidize they

21 produce very low levels of oxidation byproducts. This is in marked contrast to

22 the known art, where excellent oxygen absorbers can be obtained from the

23 use of linear unsaturated compounds compound with a transition metal salt,

24 and a photoinitiator, but where the levels of oxidation byproducts are

25 excessively high. It is thought that this improvement is obtained because mild

26 oxidation of cyclohexene does not break bonds on the ring structure whilst

27 oxidation of linear unsaturated material such as linoleic acid or vegetable oil

1 under similar conditions produces smaller molecules by chain scission. When  
2 incorporated into polymers, the cyclohexene containing systems are found to  
3 produce considerably less volatile byproducts than the linear unsaturated  
4 materials.

5 The compositions of this invention are significantly cleaner than those  
6 described in the prior art, they do not require the use of high levels of adjuncts  
7 to absorb the undesirable byproducts. Such absorbent additives are known in  
8 the art, for example see U.S. 5,834,079 and U.S. 08/857,276. It is also well  
9 known in the art that such additives (zeolites and silicas) adversely affect the  
10 haze and clarity of packaging structures.

11

12 The oxygen scavenging compositions consist of:

13 (a) a polymer or lower molecular weight material containing substituted  
14 cyclohexene functionality according to the following structure (I):

15

16

17

18

19

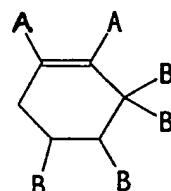
(I)

20

21

22

23



24 where A may be hydrogen or methyl and either one or two of the B groups is  
25 a heteroatom containing linkage which attaches the cyclohexene ring to  
26 the said material. The remaining B groups are hydrogen or methyl;

27

28 (b) a transition metal catalyst;

1

2 (c) an optional photoinitiator.

3

4 The compositions may be polymeric in nature or they may be lower molecular  
5 weight materials. In either case, they may be blended with further polymers  
6 or other additives. In the case of low molecular weight materials they will  
7 most likely be compounded with a carrier resin before use. The following  
8 examples represent some applications of various embodiments of the present  
9 invention currently envisaged by the patentee. These examples are not  
10 meant to be limiting nor exhaustive but merely illustrative of how the present  
11 invention may be used, or applied to address problems associated with the  
12 prior art.

13

14

15 The compositions of this invention can be used in a wide range of packaging  
16 materials, and are not restricted to flexible packaging films and articles such  
17 as pouches produced from such films. The compositions may also be used in  
18 the preparation of rigid and semi rigid packaging materials. Typical rigid and  
19 semi rigid articles include plastic, paper or cardboard cartons, bottles such as  
20 juice containers, thermoformed trays, or cups with wall thicknesses of about  
21 100 to 2000 microns. The walls of such articles comprise single or multiple  
22 layers of materials. The compositions can be used as the sole polymeric  
23 material from which one or more layers of a film are formed (i.e., the film can  
24 be a multilayer film having, for example, a gas barrier layer, a seal layer, etc.),  
25 it can be blended with other polymeric oxygen scavenging agents (such as  
26 polybutadiene) or it can be blended with one or more diluent polymers which  
27 are known to be useful in the formation of packaging film materials and which  
28 often can render the resultant film more flexible and/or processable. Suitable  
29 diluent polymers include, but are not limited to, polyethylene such as, for  
30 example, low density polyethylene, very low density polyethylene, ultra-low

1 density polyethylene, high density polyethylene, and linear low density  
2 polyethylene; polyesters such as, for example, polyethylene terephthalate  
3 (PET); polyvinyl chloride (PVC); polyvinylidene chloride (PVDC); and ethylene  
4 copolymers such as ethylene/vinyl acetate copolymer, ethylene/alkyl  
5 (meth)acrylate copolymers, ethylene/(meth)acrylic acid copolymers, and  
6 ionomers. Blends of different diluent polymers also can be used.

7

8 The compositions of this invention can also be used in non integral packaging  
9 components such as coatings, bottle cap liners, adhesive and non adhesive  
10 sheet inserts, coupons, gaskets, sealants or fibrous mass inserts.

11

12 Generally, the foregoing diluent polymers are semi-crystalline materials.  
13 Advantageously, the polymeric component of the composition of the present  
14 invention can be crystalline or semi-crystalline at ambient conditions and,  
15 accordingly, can be especially compatible with such diluent polymers.

16 Selection of a particular diluent polymer(s) depends largely on the article to  
17 be manufactured and the end use thereof. For instance, certain polymers are  
18 known by the ordinarily skilled artisan to provide clarity, cleanliness, barrier  
19 properties, mechanical properties, and/or texture to the resultant article.

20

21 In combination with the polymeric component, the oxygen scavenging  
22 composition of the present invention includes a transition metal compound as  
23 an oxygen scavenger catalyst. The transition metal catalyst can be a salt  
24 which includes a metal selected from the first, second, or third transition  
25 series of the Periodic Table. The metal preferably is Rh, Ru, or one of the  
26 elements in the series of Sc to Zn (i.e., Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, and  
27 Zn), more preferably at least one of Mn, Fe, Co, Ni, and Cu, and most  
28 preferably Co. Suitable anions for such salts include, but are not limited to,  
29 chloride, acetate, oleate, stearate, palmitate, 2-ethylhexanoate,  
30 neodecanoate, and naphthenate. Representative salts include cobalt (II)

1 2-ethylhexanoate, cobalt oleate, and cobalt (II) neodecanoate. (The metal  
2 salt also can be an ionomer, in which case a polymeric counterion is  
3 employed.)

4

5 When used in forming a packaging article, the oxygen scavenging  
6 composition of the present invention can include only the above-described  
7 polymers and a transition metal catalyst. However, photoinitiators can be  
8 added to further facilitate and control the initiation of oxygen scavenging  
9 properties. Adding a photoinitiator or a blend of photoinitiators to the oxygen  
10 scavenging composition can be preferred, especially where antioxidants have  
11 been added to prevent premature oxidation of the composition during  
12 processing and storage.

13

14 Suitable photoinitiators are known to those skilled in the art. See, e.g., PCT  
15 Publication WO 97/07161, WO 97/44364, WO 98/51758, and WO 98/51759,  
16 the teachings of which are incorporated herein by reference as if set forth in  
17 full. Specific examples of suitable photoinitiators include, but are not limited  
18 to, benzophenone, and its derivatives, such as methoxybenzophenone,  
19 dimethoxybenzophenone, dimethylbenzophenone, diphenoxybenzophenone,  
20 allyloxybenzophenone, diallyloxybenzophenone, dodecyloxybenzophenone,  
21 dibenzosuberone, 4,4'-bis(4-isopropylphenoxy)benzophenone,  
22 4-morpholinobenzophenone, 4-aminobenzophenone, tribenzoyl  
23 triphenylbenzene, tritoluoyl triphenylbenzene, 4,4'-bis(dimethylamino)-  
24 benzophenone, acetophenone and its derivatives, such as, o-methoxy-  
25 acetophenone, 4'-methoxyacetophenone, valerophenone, hexanophenone,  
26  $\alpha$ -phenyl-butyrophenone, p-morpholinopropiophenone, benzoin and its  
27 derivatives, such as, benzoin methyl ether, benzoin butyl ether, benzoin  
28 tetrahydropyranyl ether, 4-o-morpholinodeoxybenzoin, substituted and  
29 unsubstituted anthraquinones,  $\alpha$ -tetralone, acenaphthenequinone,  
30 9-acetylphenanthrene, 2-acetyl-phenanthrene, 10-thioxanthenone, 3-acetyl-

1 phenanthrene, 3-acetylindole, 9-fluorenone, 1-indanone,  
2 1,3,5-triacetylbenzene, thioxanthan-9-one, isopropylthioxanthan-9-one,  
3 xanthene-9-one, 7-H-benz[de]anthracen-7-one, 1'-acetonaphthone,  
4 2'-acetonaphthone, acetonaphthone, benz[de]anthracen-7-one,  
5 1'-acetonaphthone, 2'-acetonaphthone, acetonaphthone, benz[a]anthracene-  
6 7,12-dione, 2,2-dimethoxy-2-phenylacetophenone,  
7  $\alpha,\alpha$ -diethoxyacetophenone,  $\alpha,\alpha$ -dibutoxyacetophenone, 4-benzoyl-4'-  
8 methyl(diphenyl sulfide) and the like. Single oxygen-generating  
9 photosensitizers such as Rose Bengal, methylene blue, and  
10 tetraphenylporphine as well as polymeric initiators such as poly(ethylene  
11 carbon monoxide) and oligo[2-hydroxy-2-methyl-1-[4-(1-  
12 methylvinyl)phenyl]propanone] also can be used. However, photoinitiators  
13 are preferred because they generally provide faster and more efficient  
14 initiation. When actinic radiation is used, photoinitiators can provide initiation  
15 at longer wavelengths which are less costly to generate and present less  
16 harmful side effects than shorter wavelengths.

17

18 When a photoinitiator is present, it can enhance and/or facilitate the initiation  
19 of oxygen scavenging by the composition of the present invention upon  
20 exposure to radiation. The amount of photoinitiator can depend on the  
21 amount and type of cyclic unsaturation present in the polymer, the  
22 wavelength and intensity of radiation used, the nature and amount of  
23 antioxidants used, and the type of photoinitiator used. The amount of  
24 photoinitiator also can depend on how the scavenging composition is used.  
25 For instance, if a photoinitiator-containing composition is in a film layer, which  
26 underneath another layer is somewhat opaque to the radiation used, more  
27 initiator might be needed. However, the amount of photoinitiator used for  
28 most applications ranges from about 0.01 to about 10% (By wt.) of the total  
29 composition. Oxygen scavenging can be initiated by exposing an article

1 containing the composition of the present invention to actinic or electron  
2 beam radiation, as described below.  
3  
4 One or more antioxidants can be incorporated into the scavenging  
5 composition of the present invention to retard degradation of the components  
6 during compounding and film formation. Although such additives prolong the  
7 induction period for oxygen scavenging activity to occur in the absence of  
8 irradiation, the layer or article (and any incorporated photoinitiator) can be  
9 exposed to radiation at the time oxygen scavenging properties are required.  
10 Suitable antioxidants include 2,6-di(t-butyl)-4-methylphenol(BHT),  
11 2,2'-methylene-bis(6-t-butyl-p-cresol), triphenylphosphite, tris-  
12 (nonylphenyl)phosphite, dilaurylthiodipropionate, vitamin E ( $\alpha$ -tocopherol),  
13 octadecyl 3,5-di-tert-butyl-4-hydroxyhydrocinnamate,  
14 tetrakis[methylene(3,5-di-tert-butyl-4-hydroxyhydrocinnamate)]methane and  
15 the like.  
16  
17 When an antioxidant is included as part of the composition of the present  
18 invention, it preferably is present in an amount which prevents oxidation of the  
19 components of the oxygen scavenging composition as well as other materials  
20 present in a resultant blend during formation and processing; however, the  
21 amount preferably is less than that which interferes with the scavenging  
22 activity of the resultant layer, film, or article after initiation has occurred. The  
23 amount needed in a given composition can depend on the components  
24 present therein, the particular antioxidant used, the degree and amount of  
25 thermal processing used to form the shaped article, and the dosage and  
26 wavelength of radiation applied to initiate oxygen scavenging. Typically, such  
27 antioxidant(s) are used in an amount of from about 0.01 to about 1% (by wt.).  
28  
29 Other additives that also can be included in the oxygen scavenging  
30 composition of the present invention include, but are not necessarily limited

1 to, fillers, pigments, dyestuffs, processing aids, plasticizers, antifog agents,  
2 antiblocking agents, and the like.

3

4 The amounts of the components used in the oxygen scavenging composition  
5 of the present invention can affect the use and effectiveness of this  
6 composition. Thus, the amounts of polymer, transition metal catalyst, and  
7 any photoinitiator, antioxidant, polymeric diluents, additives, etc., can vary  
8 depending on the desired article and its end use. For example, one of the  
9 primary functions of the polymer described above is to react irreversibly with  
10 oxygen during the scavenging process, while a primary function of the  
11 transition metal catalyst is to facilitate this process. Thus, to a large extent,  
12 the amount of polymer present affects the oxygen scavenging capacity of the  
13 composition, i.e., the amount of oxygen that the composition can consume,  
14 while the amount of transition metal catalyst affects the rate at which oxygen  
15 is consumed as well as the induction period.

16

17 The composition of the present invention can provide oxygen scavenging  
18 properties at a desirable rate and capacity while having good processing and  
19 compatibility properties relative to compositions including conventional non-  
20 cyclic ethylenically unsaturated polymers. Thus, the present composition can  
21 be used to provide, by itself or as a blend with diluent film-forming polymers  
22 such as polyolefins and the like, a packaging material or film that can be  
23 manufactured and processed easily. Further, the subject oxygen scavenging  
24 composition will deplete the oxygen within a package cavity without  
25 substantially detracting from the color, taste, and/or odor of the product  
26 contained therein.

27

28 The amount of the polymeric scavenging component contained in the subject  
29 composition can range from about 1 to almost about 100%, preferably from  
30 about 5 to about 97.5%, more preferably from about 10 to 95%, even more

1 preferably from about 15 to about 92.5%, still more preferably from about 20  
2 to about 90%, (with all the foregoing percentages being by weight) of the  
3 composition or layer made therefrom. Typically, the amount of transition  
4 metal catalyst can range from 0.001 to 1% (by wt.) of the scavenging  
5 composition, based on the metal content only (i.e., excluding ligands,  
6 counterions, etc.). Where one or more other scavenging compounds and/or  
7 diluent polymers are used as part of the composition, such other materials  
8 can make up as much as 99%, preferably up to about 75%, by weight of the  
9 scavenging composition. Any further additives employed normally do not  
10 make up more than 10%, preferably no more than about 5%, by weight of the  
11 scavenging composition.

12

13 As indicated above, the composition of the present invention can be used to  
14 produce a scavenging monolayer film, a scavenging layer of a multilayer film,  
15 or other articles for a variety of packaging applications. Single layer articles  
16 can be prepared readily by extrusion processing. Multilayer films typically are  
17 prepared using coextrusion, coating, lamination or processing. Multilayer  
18 films typically are prepared using coextrusion, coating, lamination or  
19 extrusion/lamination as taught in, for example, U.S. Patents 5,350,622 and  
20 5,529,833, the teachings of which are incorporated herein by reference as if  
21 set forth in full. At least one of the additional layers of multilayer article can  
22 include a material having a permeance to oxygen of no more than about  
23  $5.8 \times 10^{-8} \text{ cm}^3/\text{m}^2\text{-s}\text{-Pa}$  (i.e., about  $500 \text{ cm}^3/\text{m}^2\text{-24 hours}\text{-atm}$ ) at about 25°C.  
24 Polymers which are commonly used in such oxygen barrier layers include  
25 poly(ethylene/vinyl alcohol), poly(vinyl alcohol), polyacrylonitrile, PVC, PVDC,  
26 PET, silica, and polyamides such as nylon 6, MXD6, nylon 66, as well as  
27 various amide copolymers. (Metal foil layers can also provide oxygen barrier  
28 properties.) Other additional layers can include one or more layers which are  
29 permeable to oxygen. In one preferred packaging construction, especially  
30 flexible packages for food, the layers can include (in order starting from the

1 outside of the package to the innermost layer of the package) (a) an oxygen  
2 barrier layer, (b) a scavenging layer, i.e. one that includes the scavenging  
3 composition described supra, and optionally, (c) an oxygen permeable layer.  
4 Control of the oxygen barrier property of layer (a) provides a means to  
5 regulate the scavenging life of the package by limiting the rate of oxygen  
6 entry to the scavenging layer (b), thus limiting the rate of consumption of  
7 scavenging capacity. Control of the oxygen permeability of layer (c) provides  
8 a means to set an upper limit on the rate of oxygen scavenging for the overall  
9 structure independent of the composition of scavenging layer (b). This can  
10 serve the purpose of extending the handling lifetime of the film in the  
11 presence of air prior to sealing of the package. Furthermore, layer (c) can  
12 provide a barrier to migration of the individual components or byproducts of  
13 the scavenging layer into the package interior. The term "exposed to the  
14 interior" refers to a portion of a packaging article having the subject  
15 scavenging composition which is either directly exposed or indirectly exposed  
16 (via layers which are O<sub>2</sub> permeable) to the interior cavity having oxygen  
17 sensitive product. Even further, layer (c) also can improve the heat  
18 sealability, clarity, and/or resistance to blocking of the multilayer film. Further  
19 additional layers such as the layers, easy open layers, and seal layers can  
20 also be used. Polymers typically used in such tie layers include, for example,  
21 anhydride functional polyolefins.

22  
23 The method of the present invention includes exposing the above-described  
24 composition to a package cavity having an oxygen sensitive product therein.  
25 A preferred embodiment provides for including a photoinitiator as part of the  
26 subject composition and subjecting a film, layer, or article that includes such a  
27 composition to radiation so as to initiate oxygen scavenging at desired rates.  
28 The thermal radiation used in heating and processing polymers typically used  
29 in packaging films (e.g., 100-250°C) advantageously does not trigger the  
30 oxygen scavenging reaction.

1  
2 The initiating radiation preferably is actinic, e.g., UV or visible light having a  
3 wavelength of from about 200 to about 750 nm, preferably of from about 200  
4 to 600 nm, and most preferably from about 200 to 400 nm. Such light can be  
5 delivered in a continuous or pulsed manner. The layer, film, etc., containing  
6 the oxygen scavenging composition preferably is exposed to such radiation  
7 until it receives at least about 1 J/g of radiation, more preferably until it  
8 receives a dose in the range of about 10 to about 2000 J/g. The radiation  
9 also can be electron-beam radiation at a dosage of at least about 2 kiloGray  
10 (kG), preferably from about 10 to about 100 kG. Other potential sources of  
11 radiation include ionizing radiation such as gamma, X-ray, and corona  
12 discharge. Duration of exposure depends on several factors including, but  
13 not limited to, the amount and type of photoinitiator present, thickness of the  
14 layers to be exposed, thickness and opacity of intervening layers, amount of  
15 any antioxidant present, and the wavelength and intensity of the radiation  
16 source.

17  
18 When using oxygen scavenging layers or articles, irradiation can occur during  
19 or after the layer or article is prepared. If the resulting layer or articles is to be  
20 used to package an oxygen sensitive product, exposure can be just prior to,  
21 during, or after packaging. For best uniformity of radiation, exposure  
22 preferably occurs at a processing stage where the layer or article is in the  
23 form of a flat sheet. For further information on initiation via irradiation, the  
24 reader is directed to PCT publications WO 98/05555 and WO 98/05703, as  
25 well as PCT 97/13598, 97/13370, 97/13369, the teachings of which are  
26 incorporated herein by reference.

27  
28 Determining the oxygen scavenging rate and capacity of a given oxygen  
29 scavenging composition contemplated for a particular use can be beneficial.  
30 To determine the rate, the time elapsed before the scavenger depletes a

1 certain amount of oxygen from a sealed container is measured. In some  
2 instances, the rate can be determined adequately by placing a film containing  
3 the desired scavenging composition in an air-tight, sealed container of an  
4 oxygen containing atmosphere, e.g., air which typically contains 20.6% (by  
5 vol.) O<sub>2</sub>. Over time, samples of the atmosphere inside the container are  
6 removed to determine the percentage of oxygen remaining. (Usually, the  
7 specific rates obtained vary under different temperature and atmospheric  
8 conditions. Atmospheres having lower initial oxygen content and/or  
9 maintained under low temperature conditions provide a more stringent test of  
10 the scavenging ability and rate of a composition. The rates which follow are  
11 at room temperature and one atmosphere of air, unless otherwise specified.)  
12 When an active oxygen barrier is needed, a useful scavenging rate can be as  
13 low as about 0.05 cm<sup>3</sup> oxygen per gram of the polymer in the scavenging  
14 composition per day in air at 25°C and at 1 atm (101.3 kPa). However, in  
15 most instances, the present composition has a rate equal to or greater than  
16 about 5.8 x 10<sup>-8</sup> cm<sup>3</sup>/g•s (0.5 cm<sup>3</sup>/g•day), even up to or greater than about  
17 5.8 x 10<sup>-5</sup> cm<sup>3</sup>/g•s (5 cm<sup>3</sup>/g•day). Further, films or layers including the subject  
18 composition are capable of a scavenging rate greater than about  
19 1.2 x 10<sup>-4</sup> cm<sup>3</sup>/m<sup>2</sup>•s (10 cm<sup>3</sup>/m<sup>2</sup>•day) and under some conditions, greater than  
20 about 2.9 x 10<sup>-4</sup> cm<sup>3</sup>/m<sup>2</sup>•s (25 cm<sup>3</sup>/m<sup>2</sup>•day). (Generally, films or layers  
21 generally deemed suitable for use as an active oxygen barrier can have a  
22 scavenging rate as low as 1.2 x 10<sup>-5</sup> cm<sup>3</sup>/m<sup>2</sup>•s (1 cm<sup>3</sup>/m<sup>2</sup>•day) when measured  
23 in air at 25°C and 101 kPa (1 atm). Such rates make those layers suitable for  
24 scavenging oxygen from within a package, as well as suitable for active  
25 oxygen barrier applications.  
26  
27 When the method of the present invention is to be used in an active oxygen  
28 barrier application, the initiated oxygen scavenging activity, in combination  
29 with any oxygen barriers, preferably creates an overall oxygen permeance of  
30 less than about 1.1 x 10<sup>-10</sup> cm<sup>3</sup>/m<sup>2</sup>•s•Pa (1.0 cm<sup>3</sup>/m<sup>2</sup>•day•atm) at 25°C. The

1    oxygen scavenging capacity preferably is such that this value is not exceeded  
2    for at least two days.  
3  
4    Once scavenging has been initiated, the scavenging composition, layer, or  
5    article prepared therefrom preferably is able to scavenge up to its capacity,  
6    i.e., the amount of oxygen which the scavenger is capable of consuming  
7    before it becomes ineffective. In actual use, the capacity required for a given  
8    application can depend on the quantity of oxygen initially present in the  
9    package, the rate of oxygen entry into the package in the absence of the  
10   scavenging property, and the intended shelf life for the package. When using  
11   scavengers that include the composition of the present invention, the capacity  
12   can be as low as 1 cm<sup>3</sup>/g, but can be 50 cm<sup>3</sup>/g or higher. When such  
13   scavengers are in a layer of a film, the layer preferably has an oxygen  
14   capacity of at least about 9.8 cm<sup>3</sup>/m<sup>2</sup> per  $\mu$ m thickness (1200 cm<sup>3</sup>/m<sup>2</sup> per mil).  
15  
16   The composition of the present invention has been found to be capable of  
17   providing a film, layer or article which substantially retains its physical  
18   properties (e.g., tensile strength and modulus) even after substantial oxygen  
19   scavenging has occurred. In addition, the present composition does not  
20   provide significant amounts of byproducts and/or effluents, which can impart  
21   an undesired taste, color, and/or odor to the packaged product.  
22  
23   This invention relates to an oxygen scavenging polymer composition  
24   comprising cyclic allylic pendent groups which can be used in oxygen  
25   scavenging packaging material which have either no or low volatile oxidation  
26   by-products. Minimizing volatile by-products reduces the problem of  
27   organoleptics in oxygen scavenging food packaging.  
28   The polymer composition with cyclic allylic pendent groups can be made by  
29   grafting methyl cyclohex-1-ene-4-methanol, cyclohex-1-ene-4-methanol

1 (1,2,5,6-tetrahydrobenzyl alcohol) and cyclohex-1-ene-4-propanol onto EMAC  
2 resins by transesterification of the corresponding alcohols or transamidation  
3 of the corresponding amines with the methyl esters on EMAC to give modified  
4 EMAC having pendent cyclic olefins (see Figure 1). The composition can  
5 also be made by direct polymerization.

6 The esterification, transesterification, amidation or transamidation reaction  
7 can be a solution reaction or by reactive extrusion. The catalysts can be any  
8 one of strong non-oxidizing acids, tertiary amines, Group I alkoxides,  
9 Group IVB alkoxides and Group IVA metal organics. The level of olefin in the  
10 final products can be controlled by the level of transesterification and the  
11 methyl ester content of the start EMAC. The molecular weight of the  
12 polymers largely depends on the molecular weight of the EMAC feeds.

13 In a preferred embodiment, these products are combined with a transition-  
14 metal salt to catalyze the oxygen scavenging properties of the materials. A  
15 transition-metal salt, as the term is used here, comprises an element chosen  
16 from the first, second and third transition series of the periodic table of the  
17 elements, particularly one that is capable of promoting oxidation reactions.  
18 This transition-metal salt is in a form which facilitates or imparts scavenging of  
19 oxygen by the composition of this invention. A plausible mechanism, not  
20 intended to place limitations on this invention, is that the transition element  
21 can readily inter-convert between at least two oxidation states and facilitates  
22 formation of free radicals. Suitable transition-metal elements include, but are  
23 not limited to, manganese II or III, iron II or III, cobalt II or III, nickel II or III,  
24 copper I or II, rhodium II, III or IV, and ruthenium. The oxidation state of the  
25 transition-metal element when introduced into the composition is not  
26 necessarily that of the active form. It is only necessary to have the transition-  
27 metal element in its active form at or shortly before the time that the  
28 composition is required to scavenge oxygen. The transition-metal element is

- 1    preferably iron, nickel or copper, more preferably manganese and most
- 2    preferably cobalt.
  
- 3    Suitable counter-ions for the transition metal element are organic or inorganic
- 4    anions. These include, but are not limited to, chloride, acetate, stearate,
- 5    oleate, palmitate, 2-ethylhexanoate, citrate, glycolate, benzoate,
- 6    neodecanoate or naphthenate. Organic anions are preferred. Particularly
- 7    preferable salts include cobalt 2-ethylhexanoate, cobalt benzoate, cobalt
- 8    stearate, cobalt oleate and cobalt neodecanoate. The transition-metal
- 9    element may also be introduced as an ionomer, in which case a polymeric
- 10   counter-ion is employed.
  
- 11   The composition of the present invention when used in forming a oxygen
- 12   scavenging packaging article can be composed solely of the above described
- 13   polymer and transition metal catalyst. However, components, such as
- 14   photoinitiators, can be added to further facilitate and control the initiation of
- 15   oxygen scavenging properties. For instance, it is often preferable to add a
- 16   photoinitiator, or a blend of different photoinitiators, to the oxygen scavenger
- 17   compositions, especially when antioxidants are included to prevent premature
- 18   oxidation of that composition during processing.
  
- 19   Suitable photoinitiators are well known in the art. Such photoinitiators are
- 20   discussed in U.S. Patent No. 5,211,875. It is also discussed in U.S. Patent
- 21   Application Serial No. 08/857,325, in which some of the present inventors
- 22   were contributing inventors and which is incorporated herein by reference.
- 23   Specific examples include, but are not limited to, benzophenone, o-methoxy-
- 24   benzophenone, acetophenone, o-methoxy-acetophenone,
- 25   acenaphthenequinone, methyl ethyl ketone, valerophenone, hexanophenone,
- 26    $\alpha$ -phenyl-butyrophenone, p-morpholinopropiophenone, dibenzosuberone,
- 27   4-morpholinobenzophenone, benzoin, benzoin methyl ether,
- 28   4-o-morpholinodeoxybenzoin, p-diacetylbenzene, 4-aminobenzophenone,

1 4'-methoxyacetophenone, substituted and unsubstituted anthraquinones,  
2  $\alpha$ -tetralone, 9-acetylphenanthrene, 2-acetyl-phenanthrene,  
3 10-thioxanthone, 3-acetyl-phenanthrene, 3-acetylindole, 9-fluorenone,  
4 1-indanone, 1,3,5-triacetylbenzene, thioxanthen-9-one, xanthene-9-one,  
5 7-H-benz[de]anthracen-7-one, benzoin tetrahydropyranyl ether,  
6 4,4'-bis(dimethylamino)-benzophenone, 1'-acetonaphthone,  
7 2'-acetonaphthone, acetonaphthone and 2,3-butanedione,  
8 benz[a]anthracene-7,12-dione, 2,2-dimethoxy-2-phenylacetophenone,  
9  $\alpha,\alpha$ -diethoxy-acetophenone,  $\alpha,\alpha$ -dibutoxyacetophenone, etc. Singlet oxygen  
10 generating photosensitizers such as Rose Bengal, methylene blue, and  
11 tetraphenyl porphine may also be employed as photoinitiators. Polymeric  
12 initiators include polyethylene carbon monoxide and oligo[2-hydroxy-2-  
13 methyl-1-[4-(1-methylvinyl)phenyl]propanone]. Use of a photoinitiator is  
14 preferable because it generally provides faster and more efficient initiation.

15 When a photoinitiator is used, its primary function is to enhance and facilitate  
16 the initiation of oxygen scavenging upon exposure to radiation. The amount  
17 of photoinitiator can vary. In many instances, the amount will depend on the  
18 amount and type of oxygen scavenging polymer in the present invention, the  
19 wavelength and intensity of radiation used, the nature and amount of  
20 antioxidants used, as well as the type of photoinitiator used. The amount of  
21 photoinitiator also depends on how the scavenging composition is used. For  
22 instance, if the photoinitiator-coating composition is placed underneath a layer  
23 which is somewhat opaque to the radiation used, more initiator may be  
24 needed. For most purposes, however, the amount of photoinitiator, when  
25 used, will be in the range of 0.01 to 10% by weight of the total composition.  
26 The initiating of oxygen scavenging can be accomplished by exposing the  
27 packaging article to actinic or electron beam radiation, as described below.

- 1   Antioxidants may be incorporated into the scavenging compositions of this
- 2   invention to control degradation of the components during compounding and
- 3   shaping. An antioxidant, as defined herein, is any material which inhibits
- 4   oxidative degradation or cross-linking of polymers. Typically, such
- 5   antioxidants are added to facilitate the processing of polymeric materials
- 6   and/or prolong their useful shelf-life.
  
- 7   Antioxidants such as Vitamin E, Irganox® 1010, Irganox® 1076,
- 8   2,6-di(t-butyl)-4-methyl-phenol(BHT), 2,6-di(t-butyl)-4-ethyl-phenol (BHEB),
- 9   2,2'-methylene-bis(6-t-butyl-p-cresol), triphenylphosphite,
- 10   tris-(nonylphenyl)phosphite and dilaurylthiodipropionate would be suitable for
- 11   use with this invention.
  
- 12   When an antioxidant is included as part of the present composition, it should
- 13   be used in amounts which will prevent oxidation of the scavenger
- 14   composition's components as well as other materials present in a resultant
- 15   blend during formation and processing but the amount should be less than
- 16   that which would interfere with the scavenging activity of the resultant layer,
- 17   film or article. The particular amount needed will depend on the particular
- 18   components of the composition, the particular antioxidant used, the degree
- 19   and amount of thermal processing used to form the shaped article, and the
- 20   dosage and wavelength of radiation applied to initiate oxygen scavenging and
- 21   can be determined by conventional means. Typically, they are present in
- 22   about 0.01 to 1% by weight.
  
- 23   Other additives which may also be included in oxygen scavenger layers
- 24   include, but are not necessarily limited to, fillers, pigments, dyestuffs,
- 25   stabilizers, processing aids, plasticizers, fire retardants, anti-fog agents, etc.
  
- 26   The amounts of the components which are used in the oxygen scavenging
- 27   compositions, or layers have an effect on the use, effectiveness and results of

1 this method. Thus, the amounts of polymer, transition metal catalyst and any  
2 photoinitiator, antioxidant, polymeric diluents and additives, can vary  
3 depending on the article and its end use.

4 For instance, one of the primary functions of the polymer described above is  
5 to react irreversibly with oxygen during the scavenging process, while the  
6 primary function of the transition metal catalyst is to facilitate this process.  
7 Thus, to a large extent, the amount of polymer present will affect the oxygen  
8 scavenging capacity of the composition, i.e., affect the amount of oxygen that  
9 the composition can consume. The amount of transition metal catalyst will  
10 affect the rate at which oxygen is consumed. Because it primarily affects the  
11 scavenging rate, the amount of transition metal catalyst may also affect the  
12 onset of oxygen scavenging (induction period).

13 It has been found that the subject polymers, when used as part of the present  
14 composition, provide oxygen scavenger properties at desirable rate and  
15 capacity while causing the composition to have enhanced processability and  
16 compatibility properties over conventional ethylenically-unsaturated polymers.

17 Thus, the present composition can be used to provide, by itself or as a blend  
18 with diluent polymers, such as polyolefins and the like, a packaging material  
19 or film having enhanced processability properties. Further, the present  
20 composition consumes and depletes the oxygen within a package cavity  
21 without substantially detracting from the color, taste and/or odor of the  
22 product contained within the package cavity.

23 The amount of the above-described polymer contained as part of the present  
24 composition may range from about 1 to 100% by weight of the composition or  
25 layer composed of said composition in which both polymer and transition  
26 metal catalyst are present (hereinafter referred to as the "scavenging  
27 composition", e.g., in a coextruded film or container, the scavenging  
28 composition would comprise the particular layer(s) in which both the

- 1 copolymer and transition metal catalyst components are present together).
- 2 Typically, the amount of transition metal catalyst may range from 0.001 to 1%
- 3 (10 to 10,000 ppm) of the scavenging composition, based on the metal
- 4 content only (excluding ligands, counterions, etc.). In the event the amount of
- 5 transition metal catalyst is less than 1%, it follows that the polymer and any
- 6 additives will comprise substantially all of the remainder of the composition.
- 7 The polymer of the present invention may further be combined with other
- 8 polymeric oxygen scavenger agents.
  
- 9 Any further additives employed normally will not comprise more than 10% of
- 10 the scavenging composition, with preferable amounts being less than 5% by
- 11 weight of the scavenging composition.
  
- 12 Optionally, the compositions and process of this invention can include
- 13 exposure of the polymer containing the oxygen scavenging-promoting
- 14 transition metal to actinic radiation to reduce the induction period, if any,
- 15 before oxygen scavenging commences. A method is known for initiating
- 16 oxygen scavenging by exposing a film comprising an oxidizable organic
- 17 compound and a transition metal catalyst to actinic radiation. A composition
- 18 of the present invention which has a long induction period in the absence of
- 19 actinic radiation but a short or non-existent induction period after exposure to
- 20 actinic radiation is particularly preferred. They maintain a high capability for
- 21 scavenging oxygen upon activation with actinic radiation. Thus, oxygen
- 22 scavenging can be activated when desired.
  
- 23 The radiation used in this method should be actinic, e.g., ultraviolet or visible
- 24 light having a wavelength of about 200 to 750 nanometers (nm), and
- 25 preferably having a wavelength of about 200 to 600 nm, and most preferably
- 26 from about 200 to 400 nm. When employing this method, it is preferable to
- 27 expose the oxygen scavenger to at least 0.01 Joule per gram of scavenging
- 28 composition. A typical amount of exposure is in the range of 10 to

1    2000 Joules per gram. The radiation can also be an electron beam radiation  
2    at a dosage of about 2 to 200 kiloGray, preferably about 10 to 100 kiloGray.  
3    Other sources of radiation include ionizing radiation such as gamma, X-rays  
4    and corona discharge. The duration of exposure depends on several factors  
5    including, but not limited to, the amount and type of photoinitiator present,  
6    thickness of the layers to be exposed, thickness and opacity of intervening  
7    layers amount of any antioxidant present, and the wavelength and intensity of  
8    the radiation source. The radiation provided by heating of polyolefin and the  
9    like polymers (e.g., 100-250°C) during processing does not cause triggering.

10   Oxygen-scavenging compositions of the present invention are useful in many  
11   ways. The compositions can be dispersed as small particles for absorbing  
12   oxygen or can be coated onto materials such as metallic foil, polymer film,  
13   metalized film, paper or cardboard to provide, in some embodiments,  
14   scavenging properties and/or adhesive properties. The compositions are also  
15   useful in making articles such as single or multi-layer rigid thick-walled plastic  
16   containers or bottles (typically, between 5 and 100 mils in thickness) or in  
17   making single or multi-layer flexible films, especially thin films (less than  
18   5 mils, or even as thin as about 0.25 mil). Some of the compositions of the  
19   present invention are easily formed into films using well-known means.  
20   These films can be used alone or in combination with other films or materials.

21   The compositions of the present invention may be further combined with one  
22   or more polymers, such as thermoplastic polymers which are typically used to  
23   form film layers in plastic packaging articles. In the manufacture of certain  
24   packaging articles, well-known thermosets can also be used as a polymeric  
25   diluent.

26   Selecting combinations of a diluent and the composition of the present  
27   invention depends on the properties desired. Polymers which can be used as  
28   the diluent include, but are not limited to, polyethylene, low or very low density

1 polyethylene, polypropylene, polyvinyl chloride, and ethylene copolymers  
2 such as ethylene-vinyl acetate, ethylene-alkyl acrylates or methacrylates,  
3 ethylene-acrylic acid or methacrylic acid, and ethylene-arylic or metharylic  
4 acid ionomers. In rigid packaging applications, polystyrene is often used.  
5 Blends of different diluents may also be used. However, as indicated above,  
6 the selection of the polymeric diluent largely depends on the article to be  
7 manufactured and the end use. Such selection factors are well known in the  
8 art.

9 If a diluent polymer such as a thermoplastic is employed, it should further be  
10 selected according to its compatibility with the composition of the present  
11 invention. In some instances, the clarity, cleanliness, effectiveness as an  
12 oxygen-scavenger, barrier properties, mechanical properties and/or texture of  
13 the article can be adversely affected by a blend containing a polymer which is  
14 incompatible with the composition of the present invention.

15 A blend of a composition of the present invention with a compatible polymer  
16 can be made by dry blending or by melt-blending the polymers together at a  
17 temperature in the approximate range of 50°C to 250°C. Alternative methods  
18 of blending include the use of a solvent followed by evaporation. When  
19 making film layers or articles from oxygen-scavenging compositions, extrusion  
20 or coextrusion, solvent casting, injection molding, stretch blow molding,  
21 orientation, thermoforming, extrusion coating, coating and curing, lamination  
22 or combinations thereof would typically follow the blending.

23 Layers comprising the composition of the present invention may be in several  
24 forms. They may be in the form of stock films, including "oriented" or "heat  
25 shrinkable" films, which may ultimately be processed as bags, etc., or in the  
26 form of stretch-wrap films. The layers may also be in the form of sheet inserts  
27 to be placed in a packaging cavity. In rigid articles such as beverage  
28 containers, thermoformed trays or cups, the layer may be within the

- 1    container's walls. Even further, the layer may also be in the form of a liner
- 2    placed with or in the container's lid or cap. The layer may even be coated or
- 3    laminated onto any one of the articles mentioned above.
  
- 4    In multi-layered articles, the scavenging layer comprising the composition of
- 5    the present invention may be included with layers such as, but not necessarily
- 6    limited to, "oxygen barriers", i.e., layers of material having an oxygen
- 7    transmission rate equal to or less than 100 cubic centimeters-mil per square
- 8    meter (cc-mil/m<sup>2</sup>) per day per atmosphere pressure at room temperature, i.e.,
- 9    about 25°C. Typical oxygen barriers comprise poly(ethylene vinyl alcohol),
- 10   polyacrylonitrile, polyvinyl chloride, poly(vinylidene dichloride), polyethylene
- 11   terephthalate, silica and polyamides. Metal foil layers can also be employed.
  
- 12   Other additional layers may include one or more layers which are permeable
- 13   to oxygen. In one preferred packaging construction, especially for flexible
- 14   packaging for food, the layers include, in order starting from the outside of the
- 15   package to the innermost layer of the package, (i) an oxygen barrier layer,
- 16   (ii) a scavenging layer, i.e., the scavenging composition as defined earlier,
- 17   and, optionally, (iii) an oxygen permeable layer. Control of the oxygen barrier
- 18   property of (i) allows a means to regulate the scavenging life of the package
- 19   by limiting the rate of oxygen entry to the scavenging composition (ii), and
- 20   thus limiting the rate of consumption of scavenging capacity. Control of the
- 21   oxygen permeability of layer (iii) allows a means to set an upper limit on the
- 22   rate of oxygen scavenging for the overall structure independent of the
- 23   composition of the scavenging composition (ii). This can serve the purpose of
- 24   extending the handling lifetime of the films in the presence of air prior to
- 25   sealing of the package. Furthermore, layer (iii) can provide a barrier to
- 26   migration of the individual components in the scavenging films or by-products
- 27   of scavenging into the package interior. Even further, layer (iii) also improves
- 28   the heat-sealability, clarity and/or resistance to blocking of the multi-layer film.

- 1    Further, additional layers such as adhesive layers may also be used.
- 2    Compositions typically used for adhesive layers include anhydride functional
- 3    polyolefins and other well-known adhesive layers.
  
- 4    To determine the oxygen scavenging capabilities of a composition, the rate of
- 5    oxygen scavenging can be calculated by measuring the time that elapsed
- 6    before the article depletes a certain amount of oxygen from a sealed
- 7    container. For instance, a film comprising the scavenging component can be
- 8    placed in an air-tight, sealed container of a certain oxygen containing
- 9    atmosphere, e.g., air which typically contains 20.9% oxygen by volume.
- 10   Then, over a period of time, samples of the atmosphere inside the container
- 11   are removed to determine the percentage of oxygen remaining. The
- 12   scavenging rates of the composition and layers of the present invention will
- 13   change with changing temperature and atmospheric conditions.
  
- 14   When an active oxygen barrier is prepared, the scavenging rate can be as
- 15   low as 0.1 cc oxygen per gram of composition of the present invention per
- 16   day in air at 25°C and a 1 atmosphere pressure. However, preferable
- 17   compositions of this invention have rates equal to or greater than 1 cc oxygen
- 18   per gram per day, thus making them suitable for scavenging oxygen from
- 19   within a package, as well as suitable for active oxygen barrier applications.
- 20   Many compositions are even capable of more preferable rates equal to or
- 21   greater than 5.0 cc O<sub>2</sub> per gram per day.
  
- 22   Generally, film layers suitable for use as an active oxygen barrier can have an
- 23   oxygen transmission rate as high as 10 cc oxygen per square meter per mil
- 24   per day when measured in air at 25°C and 1 atmosphere pressure.
- 25   Preferably, a layer of this invention has an oxygen transmission rate less than
- 26   about 1 cc oxygen per square meter per mil per day, and more preferably has
- 27   an oxygen transmission rate less than about 0.2 cc oxygen per square meter
- 28   per rail per day under the same conditions, thus making it suitable for active

- 1    oxygen barrier applications as well as for scavenging oxygen from within a
- 2    package.
  
- 3    In an active oxygen barrier application, it is preferable that the combination of
- 4    oxygen barriers and any oxygen scavenging activity create an overall oxygen
- 5    transmission rate of less than about 1.0 cubic centimeter-mil per square
- 6    meter per day per atmosphere pressure at 25°C. Another definition of
- 7    acceptable oxygen scavenging is derived from testing actual packages. In
- 8    actual use, the scavenging rate requirement will largely depend on the
- 9    internal atmosphere of the package, the contents of the package and the
- 10   temperature at which it is stored.
  
- 11   In a packaging article made according to this invention, the scavenging rate
- 12   will depend primarily on the amount and nature of the composition of the
- 13   present invention in the article, and secondarily on the amount and nature of
- 14   other additives (e.g., diluent polymer, antioxidant, etc.) which are present in
- 15   the scavenging component, as well as the overall manner in which the
- 16   package is fabricated, e.g., surface area/volume ratio.
  
- 17   The oxygen scavenging capacity of an article comprising the invention can be
- 18   measured by determining the amount of oxygen consumed until the article
- 19   becomes ineffective as a scavenger. The scavenging capacity of the
- 20   package will depend primarily on the amount and nature of the scavenging
- 21   moieties present in the article, as discussed above.
  
- 22   In actual use, the oxygen scavenging capacity requirement of the article will
- 23   largely depend on three parameters of each application:
  
- 24   (1) the quantity of oxygen initially present in the package;

- 1       (2) the rate of oxygen entry into the package in the absence of the
- 2            scavenging property; and
- 3       (3) the intended shelf life for the package.

4       The scavenging capacity of the composition can be as low as 1 cc oxygen per  
5       gram, but is preferably at least 10 cc oxygen per gram, and more preferably  
6       at least 50 cc oxygen per gram. When such compositions are in a layer, the  
7       layer will preferably have an oxygen capacity of at least 250 cc oxygen per  
8       square meter per mil thickness and more preferably at least 500 cc oxygen  
9       per square meter per mil thickness.

10      Other factors may also affect oxygen scavenging and should be considered  
11     when selecting compositions. These factors include but are not limited to  
12     temperature, relative humidity, and the atmospheric environment in the  
13     package.

14      Applicants have achieved a composition for a rigid beverage and food  
15     container comprising PET and/or PEN, the container incorporating an oxygen  
16     scavenging component of cyclic olefin which oxidizes oxygen in the interior of  
17     the container without giving off odor and/or taste as a result of its oxygen  
18     scavenging function, nor does it cause a change in molecular weight. This is  
19     because the cyclic olefin oxygen scavenging component does not fragment  
20     as it oxidizes. Thus the composition maintains the structural integrity of the  
21     container while avoiding the problem of imparting oxidation byproducts to the  
22     packaged material.

23

24      EXAMPLES

25      Objects and advantages of this invention are further illustrated by the  
26     following examples. The particular materials and amounts thereof, as well as

1 other conditions and details, recited in these examples should not be used to  
2 unduly limit this invention.

3

4 Example 1

5 Preferred embodiments of the present invention include polymers and  
6 oligomers, which contain cyclohexene groups accessible to free oxygen  
7 molecules. These polymers or oligomers may be prepared from any of a  
8 number of methods though one preferred reaction comprises 1, 2, 3, 6,  
9 tetrahydrophthalic anhydride. This anhydride is a low cost monomer derived  
10 from butadiene, which makes it particularly attractive on a commercial scale.  
11 The anhydride may be used to make polyester resins such as by reaction with  
12 diols. It may also be reacted with hydroxy or polyhydroxy compounds to  
13 produce half esters suitable for subsequent use in plastic film and materials  
14 manufacture.

15

16 Example 2

17 Non-aromatic alkenyl benzyl alcohols (e.g. tetrahydrobenzyl alcohols) may  
18 also be reacted with certain compounds to produce useful scavengers. For  
19 instance tetrahydrobenzyl alcohol may be reacted with compounds containing  
20 a carboxylic acid, acid halide, ester, anhydride and/or isocyanate functionality.  
21 These compounds may be small molecules or oligomers or polymers. For  
22 example, tetrahydrobenzyl alcohol may be reacted with styrene, maleic  
23 anhydride copolymers or with polyfunctional isocyanates.

24

25 Example 3

26 Cyclohexene dimethanol compounds may be used to prepare oxygen  
27 absorbing polyesters and polyurethanes.

28

29 Example 4

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1 As another example, tetrahydrobenzoic acid and tetrahydrobenzaldehyde  
2 may also be used to modify various hydroxyl functional materials.

3

4 Example 5

5 Reactions such as the functionalization of polymers may be carried out by a  
6 reactive extrusion process. For instance this may be a transesterification  
7 process.

8

9 Example 6

10 Cyclohexene anhydride may be used in the preparation of useful oxygen  
11 scavengers. These cyclohexene anhydrides may be prepared by from a  
12 diene monomer such as butadiene with maleic anhydride. Of commercial  
13 attractiveness are their low cost and their ability to be converted into a  
14 number of useful intermediates. In addition, they may also be used to  
15 functionalize OH containing polymers. The half esters, which form rapidly  
16 when a cyclic anhydride reacts with an OH group, may be subsequently  
17 neutralized and the resultant materials dispersed in ionomers or ethylene  
18 acrylic acid copolymers (for instance).

19

20 For ease of use, small functionalized molecules such as the reaction product  
21 of four moles of tetrahydrophthalic anhydride with pentaerythritol may be  
22 prepared either by heating in a mutual solvent or by a reactive extrusion  
23 process. These may then be dispersed into a commodity polymer such as  
24 EVA.

25

26 The cyclohexene anhydrides may also be converted into linear polyesters by  
27 reaction with ethylene glycol and the like.

28

29 Example 7

1   Useful anhydrides are cyclic anhydrides and in particular the Diels Alder  
2   adducts of various alkenes. Typically this will comprise 1, 3 butadiene (and  
3   substituted derivatives) with other compounds able to complete a Diels Alder  
4   type reaction. The resulting anhydrides may then be used in the manufacture  
5   of various oxygen scavengers, and polymers containing same.

6

7   Example 8

8   Film structures, coatings, and molded articles, as well as sachets and  
9   impregnated matrices, are envisaged incorporating oxygen scavengers as  
10   discussed previously. Also included are transition metal catalysts such as  
11   used in the prior art for catalyzing oxygen scavenging reactions. Optionally  
12   initiators or triggers for the reaction may also be included.

13

14   Example 9

15

16   Preparation of a low molecular weight oxidizable oil from 3-Cyclohexene-1-  
17   carbonyl chloride and triethylene glycol.

18

19   3-Cyclohexene-1-carbonyl chloride was prepared as follows:

20

21   50g of thionyl chloride was added to 27.6g of 3-cyclohexene-1-carboxylic acid  
22   and the solution was stirred for two hours at 50°C. Excess thionyl chloride  
23   was removed under vacuum and the resulting yellow brown oil was purified  
24   by distillation under vacuum (bp 80-82°C at 18-19mm Hg).

25

26   The oil was then prepared in the following manner:

27

28   In a 250 ml flask fitted with a drying tube was placed 18.7g of 3-cyclohexene-  
29   1-carbonyl chloride and 40cc of methylene chloride. A solution of 9.6g of  
30   triethylene glycol in 20ml of methylene chloride was added and the reaction

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1 was stirred for 2 hours at room temperature, by which time the evolution of  
2 hydrochloric acid had ceased.

3

4 80ml of 10% aqueous sodium bicarbonate was added to the reaction mixture  
5 and the mixture was vigorously stirred for 45 minutes. The organic layer was  
6 collected, washed with water and then dried with magnesium sulphate. The  
7 methylene chloride was removed under reduced pressure giving a colorless  
8 oil.

9 The cyclohexene oil was compounded into a film with the following parts by  
10 weight:

11

|    |                                            |      |
|----|--------------------------------------------|------|
| 12 | Oil                                        | 12   |
| 13 | Silica                                     | 5    |
| 14 | Benzophenone                               | 0.3  |
| 15 | Cobalt (111) acetylacetone                 | 0.28 |
| 16 | Ethylene vinyl acetate copolymer (18% EVA) | 90   |

17

18 A similar film was prepared using sunflower seed oil in place of the  
19 cyclohexene based oil.

20

21 Both films were exposed to 4 minutes of UV light, then sealed in oxygen  
22 barrier bags and stored in the dark.

23

24 Both materials scavenged oxygen after photoexposure and the sunflower oil  
25 based material was a faster scavenger than the cyclohexene oil based  
26 material. However, gas chromatography of the headspace of the bags post  
27 oxidation revealed that there was a very large difference in the levels of  
28 volatile components. The cyclohexene based material produced less than  
29 3% of the volatile components produced by the sunflower oil based material.

1  
2 The cyclohexene based films were stable for more than 300 days if stored at  
3 room temperature in the absence of light (i.e., the oxygen concentration in a  
4 sealed package containing the film specimens was essentially unchanged  
5 after storage for this time period).

6

7 A similar cyclohexene based film was prepared, this time using 3,4 dimethyl-  
8 3-cyclohexene-1-carbonyl chloride as the starting material. This film was a  
9 much faster oxygen absorber than the film prepared from the unsubstituted  
10 product. The film form the substituted produced less than 10% of the total  
11 volatile components produced from an equivalent film made from sunflower  
12 oil.

13

14 The dimethyl cyclohexene based films were stable for at least two hundred  
15 days when stored at room temperature in the absence of light. The stability of  
16 similar vegetable oil based films was limited to around 50 days.

17

18 This series of experiments revealed the following:

19

- 20 1. Cyclohexene functionalized materials are effective oxygen absorbers.
- 21 2. The speed of reaction may be increased by substituting methyl groups
- 22 adjacent to the double bond.
- 23 3. Cyclic alkene based materials produce much lower levels of volatile
- 24 oxidation products than linear alkene based materials.
- 25 4. The storage stability of cyclohexene containing films is excellent.

26

27 Example 10

28 Preparation of an oxidizable polyester resin.

29

1 In a three neck round bottom flask equipped with a Dean and Stark trap,  
2 reflux condenser and nitrogen inlet/exit were placed the following materials:  
3  
4 cis-1,2,3,6-Tetrahydronaphthalic anhydride 35.54g  
5 1,4-Butanediol 20g  
6  
7 75ml of xylene was added, so that the trap was full of xylene and the mixture  
8 was brought to reflux. The reaction was refluxed for six and a half hours:  
9 0.55g of p-Toluenesulfonic acid monohydrate was added and reflux was  
10 continued for a further six and a half hours.  
11 25ml of xylene was removed from the trap and the mixture was refluxed for a  
12 further one hour. A very viscous pale colored solution was obtained.  
13  
14 The solution was extracted with methanol to remove the acid catalyst, and  
15 was diluted with dichloromethane prior to use.  
16  
17 The polymer was obtained as a 38% w/w solids solution in  
18 toluene/dichloromethane. To 12.37 g of the polymer solution was taken  
19 0.0213 g cobalt Ten-Cem® (OMG Inc.) in 5 mL of dichloromethane and  
20 0.0069 g of Quantacure™CPTX (1-chloro-4-propoxy-thioxanthone, Great  
21 Lakes Fine Chemicals) was added. The mixture was stirred for a few minutes  
22 and a film was cast onto the surface of the another film at a wet thickness of  
23 about 1 mm. A second film was formulated as follows and cast as above:  
24 12.64 g polymer solution, 0.0318 g cobalt Ten-Cem® and 0.0074 g  
25 4,4'-dimethoxybenzophenone (DMOBP, Spectrum Quality Products Inc.).  
26  
27 The dried films were irradiated for 2.5 minutes with a combination of  
28 germicidal and backlight UV lamps. The approximate dose of UVC was  
29 1350mJcm<sup>2</sup> and the approximate dose of UVA was 1950mJcm<sup>2</sup>. The

1 irradiated films were sealed in a barrier pouch along with 120cc of air. The  
2 oxygen content was monitored with time and the following results were  
3 obtained:

| Film #1, 4.7g, 1020 ppm Cobalt and 1470 ppm CPTX |                |
|--------------------------------------------------|----------------|
| Elapsed Time (days)                              | Percent Oxygen |
| 0                                                | 20.6           |
| 1                                                | 19.2           |
| 2                                                | 18.4           |
| 3                                                | 16.9           |

4

| Film #2, 4.8g, 1500 ppm Cobalt and 1480 ppm DMOBP |                |
|---------------------------------------------------|----------------|
| Elapsed Time (days)                               | Percent Oxygen |
| 0                                                 | 20.6           |
| 1                                                 | 19.3           |
| 2                                                 | 18.6           |
| 3                                                 | 17.0           |

5

6 This example illustrates that polyesters derived from tetrahydrophthalic  
7 anhydride are useful oxygen scavengers.

8

9 Example 11

10 Preparation of an oxidizable polymer from 3-Cyclohexene-1-methanol and an  
11 alternating copolymer of maleic anhydride and octadecene.

12

13 In a three neck round bottom flask equipped with condenser and nitrogen  
14 inlet was placed 20 g of poly(maleic anhydride-alt-1-octadecene). 80 cc of  
15 methylene chloride was added and the mixture was stirred to dissolve. After

1 a clear solution had been obtained 3.2g of 3-Cyclohexene-1-methanol was  
2 added, and washed into the flask with a further 10cc of methylene chloride.

3

4 The mixture was refluxed with stirring under nitrogen for two hours, then left  
5 overnight at room temperature. The solution was refluxed for a further three  
6 hours and allowed to cool to room temperature.

7

8 The polymer was obtained as a 21.9 wt. % solution in dichloromethane. To  
9 20.51 g of the polymer solution was added 0.0201 g of cobalt Ten-Cem®  
10 (OMG Inc., 22.5% Co by wt.) dissolved in 5 mL of toluene solution and  
11 0.0038 g of Quantacure™ BMS (4-benzoyl-4'-methyl(diphenyl sulfide)  
12 available from Great Lakes Fine Chemicals Ltd.). The mixture was stirred for  
13 a few minutes and a film was cast using a draw down bar to a wet film  
14 thickness of about 1 mm.

15

16 A second film was formulated as follows: 20.10 g polymer solution, 0.0474 g  
17 cobalt Ten-Cem®, 0.0079 g 4,4'-dimethylbenzophenone (DMBP, from  
18 Lancaster Synthesis). A third film was formulated as follows: 20.84 g  
19 polymer solution, 0.0398 g cobalt Ten-Cem®, 0.0085 g  
20 2-isopropylthioxanthone (ITX, First Chemical Co.).

21

22 The dried films were irradiated for 2.5 minutes with a combination of  
23 germicidal and backlight UV lamps. The approximate dose of UVC was  
24 1350 mJ/cm<sup>2</sup> and the approximate dose of UVA was 1950 mJ/cm<sup>2</sup>. The  
25 irradiated films were sealed in a barrier pouch along with about 120 cc of air.  
26 The oxygen content was monitored with time as described elsewhere. The  
27 following results were obtained:

28

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| Film Sample #1, 1.34g, with 1004 ppm Cobalt and 844 ppm BMS |                |
|-------------------------------------------------------------|----------------|
| Elapsed Time (days)                                         | Percent Oxygen |
| 0                                                           | 20.6           |
| 1                                                           | 12.2           |
| 2                                                           | 7.5            |
| 5                                                           | 6.2            |

1

| Film Sample #2, 3.04g, with 2420 ppm Cobalt and 1795 ppm DMBP |                |
|---------------------------------------------------------------|----------------|
| Elapsed Time (days)                                           | Percent Oxygen |
| 0                                                             | 20.6           |
| 1                                                             | 11.8           |
| 2                                                             | 10.0           |
| 5                                                             | 9.7            |

2

3

| Film Sample #3, 2.09g, with 1960 ppm Cobalt and 1860 ppm ITX |                |
|--------------------------------------------------------------|----------------|
| Elapsed Time (days)                                          | Percent Oxygen |
| 0                                                            | 20.6           |
| 1                                                            | 13.8           |
| 2                                                            | 10.5           |
| 5                                                            | 10.0           |

4

5 The results suggest that the reaction of a polymeric anhydride and  
6 tetrahydrobenzyl alcohol is a useful route to oxygen scavenging plastics.

7

8 Example 12

9 Preparation of a Cyclohexene containing polymer by transesterification

10

1 To a 2L resin kettle was taken 180 g of polyethylene-co-methyl acrylate  
2 (EMAC® SP2260, Chevron, 24 wt. % methyl acrylate) and 1 L of toluene.  
3 The kettle was equipped with a mechanical overhead stirrer, Dean-Stark trap  
4 and a condenser. The kettle was heated to melt the polymer. To the stirred  
5 solution was added 28.12 g of 3-cyclohexene-1-methanol, followed by the  
6 addition of 2.145 g of 4-(2-hydroxyethoxy)benzophenone. (Note: this  
7 benzophenone derivative was prepared by the method of Yoshino et al. *Bull.*  
8 *Chem Soc. Japan*, 1973, 46, 553-6 using 4-hydroxybenzophenone, ethylene  
9 carbonate and tetraethylammonium iodide.) The catalyst, titanium (IV)  
10 isopropoxide (1.05g) was added. The mixture turned yellow and the reflux  
11 rate increased. Heat was maintained for 4 hours and about 75 mL of  
12 condensate was removed in four fractions. An additional 0.5 g of titanium  
13 isopropoxide was added and heat was maintained for an additional 8 hours.  
14 Additional toluene was added as needed to maintain the reaction volume.  
15 Again an additional 0.5 g of catalyst was added and heat maintained for  
16 another 8 hours. Analysis of the condensate showed no more production of  
17 methanol. The reaction mixture was cooled to a gel and precipitated into  
18 methanol. The polymer was washed with methanol until nothing was  
19 extracted into the methanol fractions.  
20  
21 The above resin containing cyclohexene pendant groups and a covalently  
22 bound benzophenone derivative was melt compounded with 500 ppm  
23 vitamin E as the antioxidant and 10% of an EVA based cobalt (II) oleate  
24 (Shepherd Chemicals) masterbatch. The masterbatch contained 1.0% cobalt  
25 metal by weight. Samples were compression molded and cut to 197.56 cm<sup>2</sup>  
26 of UVC light (254 nm) and was sealed in an oxygen barrier pouch (Cryovac  
27 P640B) with 300 cc of air and was stored in the dark at room temperature.  
28 Headspace oxygen levels were monitored periodically by withdrawing a 4 cc  
29 sample and analyzing using a Mocon model LC 700F oxygen analyzer. The  
30 following results were obtained for the 1.9 g (7.8 mil thick) sample.

1

| Elapsed Time (days) | Percent Oxygen |
|---------------------|----------------|
| 0                   | 20.6           |
| 1                   | 15.6           |
| 5                   | 5.0            |
| 14                  | 2.1            |
| 21                  | 1.2            |

2

3 This example illustrates excellent oxygen scavenging ability from this type of  
4 polymer and the usefulness of a covalently bound photoinitiator.

5

6 Example 13

7 Preparation of oxidizable polyurethanes.

8

9 In a two necked 250ml flask equipped with reflux condenser and nitrogen  
10 inlet/exit were placed the following materials:

11

12 1,6-Diisocyanatohexane 6.5g

13 3-Cyclohexene-1,1dimethanol 5.23g

14 2-Butanone 70ml

15

16 One drop of dibutyltin dilaurate was added and the mixture was stirred under  
17 nitrogen for thirty minutes at room temperature. The mixture was then  
18 brought to reflux for a further four hours and one drop of water in 10ml of  
19 MEK was added. The mixture was refluxed for a further hour and then  
20 allowed to cool to room temperature.

21

22 A polyurethane containing cyclic unsaturation was prepared from 1,6-  
23 diisocyanatohexane and 3-cyclohexene-1,1-dimethanol. The polymer  
24 (3.912 g) was taken into 10 mL dichloromethane and a solution of 0.0243 g of

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1 cobalt Ten-Cem® (OMG Inc.) in 5 mL of dichloromethane was added. To the  
2 stirred mixture was added 0.0084 g of 4,4'-dimethylbenzophenone (DMBP,  
3 Lancaster Synthesis). The mixture was stirred for about 15 minutes. A film  
4 was cast from the solution on the surface of another film at a wet thickness of  
5 about 1 mm. The dried film was triggered and tested as described in  
6 example 3 above.

7

| 3.9g, with 1400 ppm Cobalt and 2150 ppm DMBP |                |
|----------------------------------------------|----------------|
| Elapsed Time (days)                          | Percent Oxygen |
| 0                                            | 20.6           |
| 1                                            | 18.3           |
| 4                                            | 13.1           |
| 5                                            | 9.5            |

8

9 These results suggest that polyurethanes derived from 3-Cyclohexene-1,1-  
10 dimethanol are useful oxygen absorbers. These materials and alternative  
11 formulations may be useful in formulating oxygen-scavenging adhesive resins  
12 for use in flexible packaging i.e., for use in lamination.

13

14 Example 14

15 Preparation of a poly (vinyl acetal) from poly(vinyl alcohol) and  
16 3-Cyclohexene-1-carboxaldehyde.

17

18 In a 500ml flask equipped with nitrogen inlet/exit and mechanical stirrer was  
19 placed 150 ml of a 70/30 mix of dioxane/ethanol and 10g of poly(vinyl alcohol).  
20 The mixture was stirred and 15.7g of 3-Cyclohexene-1-carboxaldehyde was  
21 added, followed by 0.25ml conc. HCl and 5 mg of hydroquinone. The mixture  
22 was refluxed for four hours, during which time the poly(vinyl alcohol) dissolved  
23 and turned a pale yellow color, 0.5g of sodium acetate was added followed by

1 2.5g of urea, both in aqueous solution. The polymer precipitated and was  
2 purified by addition of further dioxane then precipitation into water. The dried  
3 polymer was found to contain approximately 63mole% of acetal groups.

4

5 A similar polymer was prepared from 3,4-dimethyl-3-cyclohexene-1-  
6 carboxaldehyde and poly(vinyl alcohol) which contained approximately  
7 65 mole% of acetal groups.

8

9 A solution of cobalt (III) acetylacetone (20mg) and benzophenone (20mg)  
10 in methylene chloride was added with stirring to a solution (1g) of each acetal  
11 resin dissolved in 15ml of warm dioxane. The solution was poured into a  
12 150mm diameter flat bottom petri dish and the solvent was allowed to  
13 evaporate. The resultant film was held under high vacuum for 2-3 hours to  
14 remove any residual solvent. A further sample containing 30% of a dibutyl  
15 phthalate plasticiser was also prepared using the dimethyl substituted acetal  
16 resin described above.

17

18 The film samples were exposed to 4 minutes of UVA radiation and then  
19 vacuum packed in a barrier bag. 200ml of air was injected into the bag and  
20 the puncture point was isolated by heat sealing. The pouch was stored in the  
21 absence of light.

22

23 The following results were obtained for the unsubstituted resin:

24

| Elapsed Time (days) | Percent Oxygen |
|---------------------|----------------|
| 0                   | 20.6           |
| 1                   | no reading     |
| 3                   | 9.9            |
| 6                   | 7.2            |

|   |    |     |
|---|----|-----|
| 1 | 12 | 1.2 |
|---|----|-----|

2 The following results were obtained for the disubstituted resin:

| Elapsed Time (days) | Percent Oxygen |
|---------------------|----------------|
| 0                   | 20.6           |
| 1                   | 10.2           |
| 3                   | 4.3            |
| 6                   | 1.4            |
| 21                  | 0              |

3

4 The following results were obtained from the plasticised resin:

5

| Elapsed Time (days) | Percent Oxygen |
|---------------------|----------------|
| 0                   | 20.6           |
| 3                   | 3.7            |
| 4                   | 1.8            |
| 7                   | 0.2            |
| 12                  | 0              |

6

7 These results demonstrate the following principles:

8

9 1. Cyclohexene based acetal resins are effective oxygen scavengers.

10

11 2. The substituted cyclohexene rings provide faster oxygen scavengers than  
12 the unsubstituted resins.

13

14 3. A plasticiser tends to increase the rate of oxygen scavenging.

1  
2  
3  
4 Non-limiting examples are given in Examples 15 and 16 below of  
5 experimental conditions that were used for preparation of the polymers.  
6 Non-limiting examples of the resin preparation followed by steam stripping as  
7 well as compounding the polymers with oxidation catalyst, such as cobalt  
8 oleate and a photoinitiator, such as Methanone,  
9 [5'-(5'-(4-benzoylphenyl)[1,1':3', 1"-terphenyl]-4,4"-diyl]bis[phenyl- (hereinafter  
10 referred to as BBP<sup>3</sup>), and extruded into a 3-layer film having a PE/oxygen  
11 scavenging polymer/PE structure are provided in Examples 17 through 20  
12 below.  
13 Headspace studies of three layer films made by compounding catalyst  
14 package with both fresh and aged (20 months stored in air at ambient  
15 temperature) resins after UV triggering give a very fast rate of oxygen  
16 scavenging and the resulting packages are relatively non-odorous.  
17 Non-limiting examples of such studies are given in Examples 21 and 22.  
18 Furthermore, the above polymer can be further diluted by a lower cost oxygen  
19 permeable resin, such as EBAC or PE or EVA, down to 50 and even 25% of  
20 the original concentration and still maintain a high oxygen scavenging rate, as  
21 the non-limiting examples in Examples 23 and 24 show.

22  
23 Example 15

24 Polymer Preparation (C1641-6)

25 550 ml of decalin® was placed in a flask. To this was added 350 g of  
26 Chevron EMAC SP-2260 which has 24 weight % of methyl acrylate  
27 (0.9767 moles of methyl acrylate) and 0.48 g of Irganox®1076 (0.1 mole).  
28 The temperature of the mixture was gradually raised while stirring. When the

1    temperature reached approximately 120°C, 127.1 g (0.9767 moles) of  
2    3-methyl-cyclohex-1-ene-4-methanol (97%) was added. When the  
3    temperature reached approximately 140°C, 4.8 g of the catalyst  $Ti(OC_2H_5)_4$   
4    was added a portion at a time. The temperature was maintained at 170°C  
5    while stirring. The course of the reaction was observed by subjecting  
6    samples of the mixture to NMR at hourly intervals. The percent conversion is  
7    given in Table 1 below. After 5 hours of reaction, the mixture was cooled and  
8    400 ml of  $CHCl_3$  was added and the mixture was then precipitated by adding  
9    it to 4 liters of  $CH_3OH$  in a Waring blender. The precipitate is filtered and  
10   washed with  $CH_3OH$  and dried in a vacuum oven at 50°C. The dried mixture  
11   yielded 407.5 g of ethylene/methyl acrylate/methyl cyclohexene methyl  
12   acrylate (EMCM).

13

Table 1

| Time (hours) | Percent Conversion |
|--------------|--------------------|
| 1 hour       | 50%                |
| 2 hours      | 62.3%              |
| 3 hours      | 65.5%              |
| 5 hours      | 87.1%              |

14  
15   390 grams of a combination of the above prepared polymer and the same  
16   polymer prepared under the same conditions in a different batch, which  
17   together have a conversion percentage of 68.8%, was solvent coated with  
18   3.25 g cobalt-neodecanoate in 70 ml normal hexane. The mixture was  
19   tumble dried for 1.5 hours and residual solvent removed in a vacuum.

20

Example 16

22

Polymer Preparation

23   600 ml of decalin was placed in a flask. To this was added 334 grams of  
24   Chevron SP-2260 (0.9330 moles of methyl acrylate) and 0.44 g of Irganox®

1 1010 (0.1% mole). The temperature of the mixture was gradually raised while  
2 stirring. When the temperature reached approximately 120°C, 104.6 g  
3 (0.93 moles) of cyclohex-1-ene-4-methanol was added. When the  
4 temperature reached approximately 140°C, 4.4 g of the catalyst  $Ti(OC_2H_5)_4$   
5 was added a portion at a time. The temperature was maintained at 160°C  
6 while stirring. The course of the reaction was observed by subjecting  
7 samples of the mixture to NMR at hourly intervals. The percent conversion is  
8 given in Table 2 below. After 3 hours of reaction, the mixture was cooled and  
9 400 ml of  $CHCl_3$  was added and the mixture was then precipitated by adding  
10 it to 4 liters of  $CH_3OH$  in a Waring blender. The precipitate was filtered and  
11 washed with  $CH_3OH$  and dried in a vacuum oven at 50°C. The dried mixture  
12 yielded 380.5 g of polymer.

13

Table 2

14

| Time (hours) | Percent Conversion |
|--------------|--------------------|
| 1 hour       | 43.8%              |
| 2 hours      | 56.7%              |
| 3 hours      | 55.7%              |

15 185 grams of the above-prepared polymer was combined with 45 ml normal  
16 hexane and 1.54 g cobalt-neodecanoate resulting in 1000 ppm of cobalt ion  
17 and 0.0185 g Irganox® 1010 resulting in 100 ppm Irganox®. The mixture  
18 was heated and blended and then dried in a vacuum-oven. The resulting  
19 compound was extruded into a film.

20 Additionally, 185 grams of the above-prepared polymer was combined with  
21 45 ml normal hexane and 1.54 g cobalt-neodecanoate (resulting in 1000 ppm  
22 of cobalt ion) and 0.046 g Irganox® 1010 (resulting in 250 ppm Irganox®).  
23 The mixture is heated and blended and then dried in a vacuum-oven. The  
24 resulting compound is extruded into a film.

1    Example 17

## 2                    EMCM Made in ZSK-30 Extruder

3    Ethylene-methyl acrylate copolymer (EMAC) was fed into a Werner &  
4    Pfleiderer ZSK-30 twin screw extruder at 6 kg/hr, and the reactants and  
5    catalysts were added to the extruder in a subsequent reaction zone. The  
6    catalyst  $Ti(OC_3H_7)_4$  was added with the reactants at 3 mol % or at a rate of  
7    148 cc/hr. Irganox®/Toluene solution was added at 4.5 g/900 cc using a  
8    Milton Roy 29/290 mini-pump. To obtain 100 ppm of Irganox®, it must be  
9    added at 2.2 cc/min. To obtain 50 ppm of Irganox, it must be added at  
10   1.1 cc/min. Cyclohexane methyl alcohol with 1,000 ppm of an antioxidant of  
11   BHT was added via a Milton Roy dual head at 1958 cc/hr. Steam is injected  
12   into the system at 800 cc H<sub>2</sub>O/Hr at the end of the reaction zone.

13   51 lbs of EMCM product (100 ppm Irganox® 1010, 59.3% methyl alcohol  
14   (MA), 2.98 g/10 min. Melt Flow) was produced over a period of approximately  
15   2 hours.

1    Example 182                    EMCM Made in ZSK-30

3    45 lbs of EMCM product (100 ppm Irganox®1010, 2.38 g/10 min Melt Index)  
4    was extruded over a period of approximately 3 hours. A dual steam stripping  
5    setup was used in which pressurized injectors at zones 4 and 11 of the  
6    extruder pumped steam at 1076 cc/hr and 728 cc/hr, respectively. Both  
7    injectors were Pulse 680 pumps with a pressure of at least 800 psi, except at  
8    the first measured time interval when injector (No. 4) was measured at  
9    500-550 psi and injector (No. 11) was measured at 500 psi.

10    Example 1911    Co-polymerization of Styrene and 3-Cyclohexene-1-Methanol Methacrylate

12    In a 1-liter round bottom flask, 65 grams styrene (0.625 mole), 113 grams of  
13    3-cyclohexene-1-methanol methacrylate (0.625 mole), 1.25 grams of Benzoyl  
14    peroxide and 450 grams of toluene were mixed and degassed by freeze-thaw  
15    cycles. The degassed solution was polymerized at 70-75°C for 48 hours and  
16    discharged into 2 liters of methanol in a Waring Blender. The product isolated  
17    was dried in a vacuum oven at 50°C for 2 hours to give 155 grams of  
18    co-polymer. NMR analysis indicates it contains 48 mole % of styrene and  
19    52 mole % of 3-cyclohexene-1-methanol methacrylate. Tg by DSC is 66°C.

20

21    Example 2022    Oxygen Scavenging Test of Styrene/CHMA Copolymer

23    90 weight % of the above-mentioned co-polymer and 10 weight % of a EVA  
24    based Master batch containing 1 weight % of co-oleate and 1 weight % of a  
25    photoinitiator (BBP<sup>3</sup>) were processed into a 8 mil thick monolayer film. A  
26    100 cm<sup>2</sup> film was irradiated at both sides to receive 800 mJoules/cm<sup>2</sup> of

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1 254 nm UV on each side and sealed into a foil bag containing 300 cc of 1%  
 2 oxygen. The oxygen uptake was monitored up to 11 days at 4°C and at room  
 3 temperature. The results are shown in Tables 3 (4°C) and 4 (room  
 4 temperature).

5

Table 3

| Time (days) | O <sub>2</sub> Meas. Vol% | O <sub>2</sub> Meas. Vol, ml | Vol—O <sub>2</sub> Used ml | O <sub>2</sub> Uptake ml/g | O <sub>2</sub> Uptake Avg Rate cc/m <sup>2</sup> /day | Instant Rate cc/m <sup>2</sup> /day | O <sub>2</sub> Capacity cc/m <sup>2</sup> /mil |
|-------------|---------------------------|------------------------------|----------------------------|----------------------------|-------------------------------------------------------|-------------------------------------|------------------------------------------------|
| 0.0         | 1.05                      | 3.15                         | 0.00                       | 0.00                       | 0.00                                                  | 0.00                                | 0.00                                           |
| 1.1         | 0.94                      | 2.77                         | 0.32                       | 0.18                       | 14.79                                                 | 14.79                               | 1.62                                           |
| 3.9         | 0.49                      | 1.42                         | 1.63                       | 0.92                       | 20.73                                                 | 23.03                               | 8.15                                           |
| 4.8         | 0.39                      | 1.11                         | 1.91                       | 1.08                       | 19.81                                                 | 15.78                               | 9.57                                           |
| 7.0         | 0.30                      | 0.84                         | 2.17                       | 1.22                       | 15.40                                                 | 5.72                                | 10.83                                          |
| 11.0        | 0.09                      | 0.25                         | 2.74                       | 1.54                       | 12.43                                                 | 7.22                                | 13.72                                          |

6

7

Table 4

| Time (days) | O <sub>2</sub> Meas. Vol% | O <sub>2</sub> Meas. Vol, ml | Vol—O <sub>2</sub> Used ml | O <sub>2</sub> Uptake ml/g | O <sub>2</sub> Uptake Avg Rate cc/m <sup>2</sup> /day | Instant Rate cc/m <sup>2</sup> /day | O <sub>2</sub> Capacity cc/m <sup>2</sup> /mil |
|-------------|---------------------------|------------------------------|----------------------------|----------------------------|-------------------------------------------------------|-------------------------------------|------------------------------------------------|
| 0.0         | 1.04                      | 3.12                         | 0.00                       | 0.00                       | 0.00                                                  | 0.00                                | 0.00                                           |
| 1.1         | 0.48                      | 1.42                         | 1.65                       | 1.03                       | 75.28                                                 | 75.28                               | 8.26                                           |
| 3.9         | 0.09                      | 0.26                         | 2.78                       | 1.73                       | 35.40                                                 | 19.96                               | 13.92                                          |
| 4.8         | 0.04                      | 0.11                         | 2.93                       | 1.82                       | 30.26                                                 | 7.89                                | 14.63                                          |
| 7.0         | 0.01                      | 0.03                         | 3.01                       | 1.87                       | 21.39                                                 | 1.91                                | 15.05                                          |
| 11.0        | 0.01                      | 0.03                         | 3.01                       | 1.87                       | 13.64                                                 | 0.00                                | 15.05                                          |

8

9 Example 2110 Polymerization of 3-cyclohexene-1-methanol acrylate

1 75 grams (0.45 mole) of 3-cyclohexene-1-methanol acrylate (CHAA), 200 ml  
2 of toluene and 0.5 grams of Benzoyl peroxide were charged into a 500 ml  
3 round-bottomed flask and degassed by freeze-thaw cycles. The degassed  
4 solution was polymerized at 70-75°C for 48 hours. The viscous polymer  
5 solution was worked up by precipitating in methanol solution in a Waring  
6 blender. After vacuum drying at room temperature for 3 days, the product is a  
7 rubbery clear polymer which weighs 53 grams.

8

9 Example 22

10 Headspace Analysis of O<sub>2</sub> Scavenging in  
11 Dowlex® 3010/EMCM/Dowlex® 3010 Films

12 Oxygen scavenging analysis was performed using a Mocon HS750 with a  
13 headspace volume of 300 cc. The sample tested was a 0.48 g three-layer  
14 film with Dowlex® 3010 film for the two outside layers and steam stripped  
15 EMCM (59% converted) for the middle layer (50 ppm Irganox® 1010). The  
16 thickness of the layers was 0.5/1/0.5 +/- 0.1 Mil. The oxygen scavenging  
17 portion of the middle layer comprised 1000 ppm Cobalt salt, 1000 ppm BBP<sup>3</sup>  
18 and was exposed for 1.6 minutes to 254 nm UV at 1 inch to receive  
19 800 mJ/cm<sup>2</sup>. The oxygen scavenging was tested with 300 cc 1% O<sub>2</sub> at 4°C.  
20 The results of the tests are given below in Table 5. These results are plotted  
21 along with the results of Example 20 in Figure 2, which graphically plots %  
22 oxygen in headspace against time (days). The oxygen scavenging uptake  
23 capacity is based on the total weight of the three-layer film.

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1

Table 5

| Time<br>(days<br>) | O <sub>2</sub> Meas.<br>Vol% | O <sub>2</sub><br>Meas.<br>Vol, ml | Vol—O <sub>2</sub><br>Used ml | O <sub>2</sub><br>Uptake<br>ml/g | O <sub>2</sub> Uptake<br>Avg Rate<br>cc/m <sup>2</sup> /day | Instant<br>Rate cc/<br>m <sup>2</sup> /day | O <sub>2</sub><br>Capacity<br>cc/m <sup>2</sup> /mil |
|--------------------|------------------------------|------------------------------------|-------------------------------|----------------------------------|-------------------------------------------------------------|--------------------------------------------|------------------------------------------------------|
| 0.0                | 1.04                         | 3.12                               | 0.00                          | 0.00                             | 0.00                                                        | 0.00                                       | 0.00                                                 |
| 0.8                | 0.74                         | 2.18                               | 0.89                          | 1.84                             | 57.93                                                       | 57.93                                      | 44.25                                                |
| 1.9                | 0.46                         | 1.33                               | 1.70                          | 3.54                             | 45.85                                                       | 37.36                                      | 84.85                                                |
| 3.0                | 0.29                         | 0.83                               | 2.18                          | 4.54                             | 36.87                                                       | 21.87                                      | 109.08                                               |
| 5.8                | 0.14                         | 0.39                               | 2.60                          | 5.42                             | 22.46                                                       | 7.41                                       | 130.08                                               |
| 7.8                | 0.09                         | 0.25                               | 2.74                          | 5.71                             | 17.67                                                       | 3.51                                       | 136.95                                               |

2

3 Example 234 Headspace Analysis of O<sub>2</sub> Scavenging in  
5 Dowlex® 3010/EMCM/Dowlex® 3010 Films

6 Oxygen scavenging analysis was performed using a Mocon HS750 with a  
 7 headspace volume of 300 cc. The sample tested was a 0.47 g three-layer  
 8 film with Dowlex® 3010 film for the two outside layers and steam stripped  
 9 EMCM for the middle layer (50 ppm Irganox 1010)). The thickness of the  
 10 layers was 0.5/1/0.5 +/- 0.1 Mil. The oxygen scavenging portion of the middle  
 11 layer comprised 1000 ppm Cobalt salt, 1000 ppm BBP<sup>3</sup> (a photoinitiator)  
 12 exposed for 1.6 minutes to 254 nm UV at 1 inch to receive 800 mJ/cm<sup>2</sup>. The  
 13 oxygen scavenging was tested with 300 cc 1% O<sub>2</sub> at 4°C. These results are  
 14 plotted along with the results of Example 21 in Figure 2, which graphically  
 15 plots % oxygen in headspace against time (days).

1    Example 242            Headspace Analysis of O<sub>2</sub> Scavenging in Dowlex® 3010/  
3                    EBAC:EMCM/Dowlex® 3010 Films

4    Oxygen scavenging analysis was performed using a Mocon HS750 with a  
5    headspace volume of 300 cc. The sample tested was a 0.45 g three-layer  
6    film with Dowlex® 3010 film for the two outside layers and 3:1 EBAC  
7    (ethylene/butyl acrylate copolymer):EMCM (ethylene/methyl acrylate/  
8    cyclohexenyl methyl acrylate) for the middle layer (50 ppm Irganox® 1010)).  
9    The thickness of the layers was 0.5/1/0.5 +/- 0.1 Mil. The oxygen scavenging  
10   portion of the middle layer comprised 1000 ppm of Cobalt salt, 1000 ppm  
11   BBP<sup>3</sup> was exposed for 1.6 minutes to 254 nm UV at 1 inch to receive  
12   800 mJ/cm<sup>2</sup>. The oxygen scavenging was tested with 300 cc 1% O<sub>2</sub> at 4°C.  
13   These results are plotted along with the results of Example 22 in Figure 3,  
14   which graphically plots % oxygen in headspace against time (days).

15

16   Example 2517            Headspace Analysis of O<sub>2</sub> Scavenging in Dowlex® 3010/  
18                    EBAC:EMCM/Dowlex® 3010 Films

19   Oxygen scavenging analysis was performed using a Mocon HS750 with a  
20   headspace volume of 300 cc. The sample tested was a 0.47 g three-layer  
21   film with Dowlex® 3010 film for the two outside layers and 1:1 EBAC:EMCM  
22   for the middle layer (50 ppm Irganox®1010)). The thickness of the layers  
23   was 0.5/1/0.5 +/- 0.1 Mil. The oxygen scavenging portion of the middle layer  
24   comprised 1000 ppm Cobalt Oleate salt, 1000 ppm BBP<sup>3</sup> exposed for  
25   1.6 minutes at 254 nm UV at 1 inch to receive 800 mJ/cm<sup>2</sup>. The oxygen  
26   scavenging was tested with 300 cc 1% O<sub>2</sub> at 4°C. The results of the tests are  
27   given below in Table 6. These results are plotted along with the results of  
28   Example 23 in Figure 3, which graphically plots % oxygen in headspace

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1 against time (days). The oxygen scavenging uptake capacity is based on the  
 2 total weight of the 3-layer film.

3 Table 6

| Time (days) | Head-space O <sub>2</sub> (Vol%) | Head-space O <sub>2</sub> (Vol, ml) | Vol—O <sub>2</sub> Used (ml) | O <sub>2</sub> Uptake (ml/g) | O <sub>2</sub> Uptake Avg Rate (cc/m <sup>2</sup> ·day) | Instant Rate (cc/m <sup>2</sup> ·day) | O <sub>2</sub> Capacity cc/m <sup>2</sup> |
|-------------|----------------------------------|-------------------------------------|------------------------------|------------------------------|---------------------------------------------------------|---------------------------------------|-------------------------------------------|
| 0.0         | 1.09                             | 3.27                                | 0.00                         | 0.00                         | 0.00                                                    | 0.00                                  | 0.00                                      |
| 0.8         | 0.74                             | 2.18                                | 1.03                         | 2.20                         | 63.00                                                   | 63.00                                 | 51.63                                     |
| 1.8         | 0.50                             | 1.45                                | 1.73                         | 3.68                         | 48.52                                                   | 36.18                                 | 86.43                                     |
| 4.8         | 0.17                             | 0.48                                | 2.67                         | 5.8                          | 27.73                                                   | 15.51                                 | 133.45                                    |
| 6.1         | 0.12                             | 0.34                                | 2.81                         | 5.98                         | 23.17                                                   | 5.60                                  | 140.45                                    |
| 6.9         | 0.10                             | 0.28                                | 2.86                         | 6.09                         | 20.84                                                   | 3.40                                  | 143.20                                    |
| 7.9         | 0.08                             | 0.22                                | 2.92                         | 6.21                         | 18.46                                                   | 2.62                                  | 145.90                                    |

4  
 5 Example 26

6 Headspace Analysis of O<sub>2</sub> Scavenging Capacity  
 7 in Dowlex® 3010/EMCM/Dowlex® 3010 Films

8 Oxygen scavenging analysis was performed using a Mocon HS750 with a  
 9 headspace volume of 300 cc. The sample tested was a 0.47 g three-layer  
 10 film with Dowlex® 3010 film for the two outside layers and steam stripped  
 11 EMCM for the middle layer (50 ppm Irganox®1010)). The thickness of the  
 12 layers was 0.5/1/0.5 +/- 0.1 Mil. The oxygen scavenging portion of the middle  
 13 layer comprised 1000 ppm Cobalt Oleate salt, 1000 ppm BBP<sup>3</sup> exposed for  
 14 1.6 minutes to 254 nm UV at 1 inch to receive 800 mJ/cm<sup>2</sup>. The oxygen  
 15 scavenging was tested with 300 cc air at room temperature. The O<sub>2</sub> uptake  
 16 capacity is based on total weight of the 3-layer film. The results of the tests  
 17 are given below in Table 7. These results are plotted along with the results of  
 18 Example 26 in Figure 4, which graphically plots % oxygen in headspace  
 19 against time (days).

1

2 96. A layer according to claim 94, wherein the metal salt selected from  
3 the group consisting of cobalt neodecanoate, cobalt 2-ethylhexanoate, cobalt  
4 oleate and cobalt stearate.

5

6 97. A layer according to claim 91, wherein said layer in addition  
7 comprises polymeric diluent.

8

9 98. A layer according to claim 97, wherein said diluent is a thermoplastic  
10 polymer.

11 99. A layer according to claim 91, wherein said layer is adjacent to one or  
12 more additional layers.

13

14 100. A layer according to claim 99, wherein at least one additional layer is  
15 an oxygen barrier.

16

17 101. A layer according to claim 100, wherein said oxygen barrier  
18 comprises a member of the group consisting of poly(ethylene-vinyl alcohol),  
19 polyacrylonitrile, poly(vinyl chloride), polyamides, poly(vinylidene dichloride),  
20 poly(ethylene terephthalate), silica, metal foil and metalized polymeric films.

21

22 102. A layer according to claim 99, wherein one or more of said additional  
23 layer or layers is coextruded with said layer.

24

25 103. A layer according to claim 99, wherein one or more of said additional  
26 layer or layers is laminated onto said layer.

27

28 104. A layer according to claim 99, wherein one or more of said additional  
29 layer or layers is coated onto said layer.

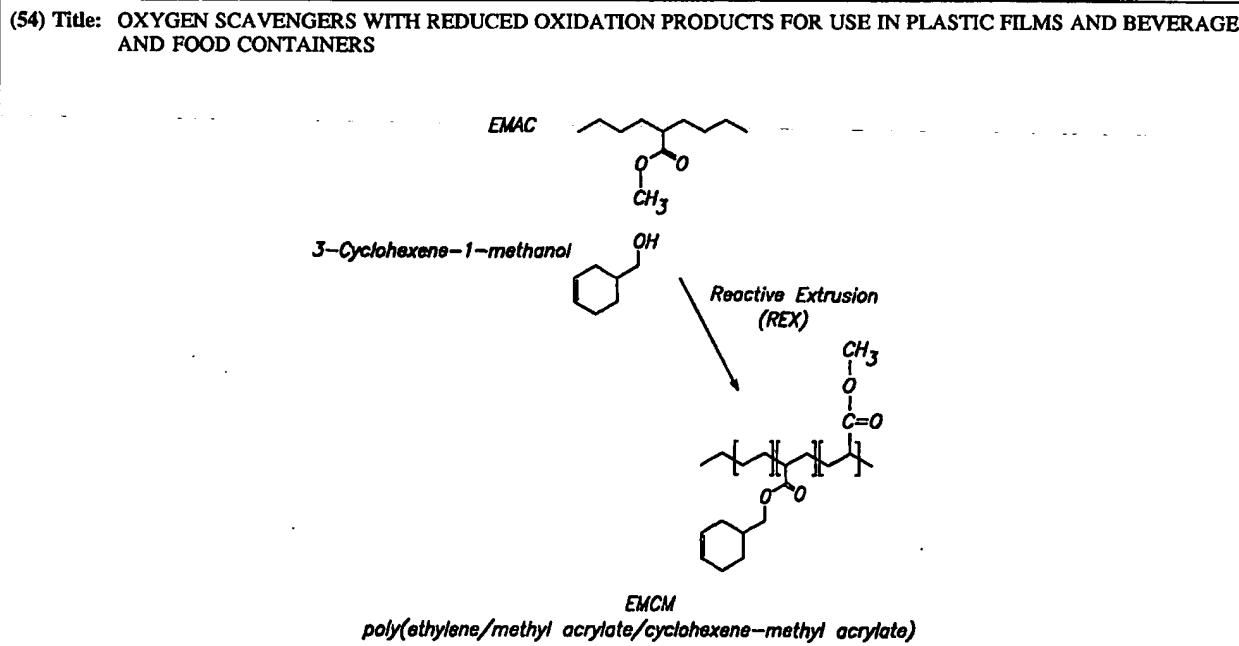
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |  |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
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| (71) Applicants: CHEVRON CHEMICAL COMPANY LLC [US/US]; 555 Market Street, San Francisco, CA 94105 (US). SEALED AIR (NZ) LIMITED [NZ/NZ]; Private Bag 3085, Corner Avalon Drive & Foreman Road (NZ).                                                                                                                                                                                                                                                                                                                                                                                                               |  |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| (72) Inventors: CHING, Ta, Yen; 10 Santa Yorma Court, Novato, CA 94945 (US). CAI, Gangfeng; 335 Glasgow Circle, Danville, CA 94526 (US). DEPREE, Craig; 27 Pembroke Street, Palmerston North (NZ). GALLAND, Mark, Steven; 2806 Chasse Ridge Drive, Orange, TX 77632 (US). GOODRICH, Joseph, L.; 3545 Wilkinson Lane, Lafayette, CA 94549 (US). LEONARD, James, P.; 545 Bret Harte Road, San Rafael, CA 94901 (US). MATTHEWS, Andrew; 106 West Shallowstone Road, Greer, SC 29650 (US). RUSSELL, Kenneth, W.; Route 10, Box 1366, Orange, TX 77630 (US). YANG, Hu; 360 Bellflower Court, San Ramon, CA 94583 (US). |  |    | Published<br><i>With international search report.</i><br><i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>                                                                                                                                                                                                                                                                                                                                                                                                                 |
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## (57) Abstract

An oxygen scavenger composition, for use in or with plastics materials, includes a polymer or oligomer having at least one cyclohexene group or functionality. The composition produces only low levels of volatile or (extractable from a plastics material in which it is incorporated) products as a consequence of oxygen scavenging. A family of polymers containing selected cyclic allylic pendent groups for oxygen scavenging packaging which has minimal organoleptic by-products after oxidation. Multilayer plastic containers for food and beverage packaging which incorporate oxygen scavenging resins which selectively oxidize upon activation without giving off odorous fragments.

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# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 99/06379

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                     |                                                                                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| A. CLASSIFICATION OF SUBJECT MATTER<br>IPC 6 C08K5/09                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                     |                                                                                |
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                     |                                                                                |
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| Minimum documentation searched (classification system followed by classification symbols)<br>IPC 6 C08K                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                     |                                                                                |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                     |                                                                                |
| Electronic data base consulted during the international search (name of data base and, where practical, search terms used)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                     |                                                                                |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                     |                                                                                |
| Category *                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                  | Relevant to claim No.                                                          |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | WO 96 40799 A (CHEVRON CHEM CO)<br>19 December 1996 (1996-12-19)<br>cited in the application<br>page 30, line 14 - page 31, line 22;<br>claims 1,3; example 44; tables 4,7-9<br>--- | 1-30                                                                           |
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| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | DE 19 00 181 A (DEUTSCHE AKADEMIE DER<br>WISSENSCHAFTEN BERLIN)<br>2 October 1969 (1969-10-02)<br>page 3, line 20-30; example 1<br>---                                              | 1,5                                                                            |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | EP 0 418 011 A (SERICOL GROUP LTD)<br>20 March 1991 (1991-03-20)<br>claims 1-6; example 1<br>---                                                                                    | 1,5                                                                            |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | -/-                                                                                                                                                                                 |                                                                                |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of box C.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                     | <input checked="" type="checkbox"/> Patent family members are listed in annex. |
| <p>* Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>                                                                           |                                                                                                                                                                                     |                                                                                |
| <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>*&amp; document member of the same patent family</p> |                                                                                                                                                                                     |                                                                                |
| Date of the actual completion of the international search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                     | Date of mailing of the international search report                             |
| 15 June 1999                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                     | 24.09.99                                                                       |
| Name and mailing address of the ISA<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl<br>Fax: (+31-70) 340-3016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                     | Authorized officer<br><br>Devries, K                                           |

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 99/06379

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document, with indication, where appropriate, of the relevant passages                      | Relevant to claim No. |
|----------|---------------------------------------------------------------------------------------------------------|-----------------------|
| A        | WO 95 02616 A (CHEVRON RES & TECH)<br>26 January 1995 (1995-01-26)<br>cited in the application<br>----- | 1                     |

**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US 99/06379

**Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.: because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
  
3.  Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

See additional sheet

1.  As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
  
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3.  As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1 - 30

**Remark on Protest**

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US 99/06379

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1. Claims: 1-30

a composition comprising: a) a polymer or oligomer with cyclohexene functionality and b) a transition metal catalyst;

2. Claims: 30-107

a polymer with cyclic olefinic pendant groups, a composition and article thereof

3. Claims: 31-41,108-128

a polymer with cyclic olefinic pendant groups, a process for its manufacture

4. Claims: 129-201

a composition containing a) a polymer b) monomers having a cyclic allylic hydrogen and c) a transition metal catalyst; a container moulded from said composition.

5. Claims: 129-201

a composition containing a) a polymer b) monomers having a cyclic benzylic hydrogen and c) a transition metal catalyst; a container moulded from said composition.

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

|                              |  |
|------------------------------|--|
| International Application No |  |
| PCT/US 99/06379              |  |

| Patent document cited in search report | Publication date | Patent family member(s) |            | Publication date |
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